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HOW TO PROPAGATE JAPANESE MID-RIVER FISHES

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Based on the degree of erosion and acculation, T. Nomitsu (1945) divided Japanese river into three geographical divisions: upper, middle and lower regions. Based on limnological and environmental factors, M. Ueno (1835) also recognized three divisions: mountain torrent, mid-torrent, and lower-torrent. Based on Mid-European ichthyological study, Hesse (1932) recognized four regions: trout, barbus, carp and river-mouth regions.

Taking above author's views into consideration, the present author have proposes four regions for the rivers found in Mid-Japan based on the distributional point of view of fresh water fishes in the rivers.

1) The Upper Fish Region is characterised by a very rapid current of water with temperature not above 8°c. and the representative fish found is *Salverinus pulvius* Hilgendorf.

2) The Mid Fish Region has fairly swiftly running water and its temperature ranges from 5° to 15°c and the characteristic fish here is *Cottus pollux* (Günther).

3) The Lower Fish Region is defined to have a temperature above 15° and is not influenced by sea water. *Cyprinus carpio* Linnaeus is best represented in this region.

4) The River-mouth Fish Region is brackish and *Mugil cephalus* (Linnaeus) is the typical representative.

Characteristics of fishes found in the middle water of a river.

The fishes found in this section of a river generally have cylindrical and bilaterally flattened. The cross-section of the body is either circular or elliptical. This type of body is hydrodynamically practical for living in this type of river. They feed chiefly on insect larvae or adhesive micro-algae. Their eggs are mostly adhesive or submerged types; and among the former, eggs of *Cottus pollux* and *Hemibarbus barbus* are distinctly adhesive *Tribolodon hakuensis* and *Zacco platypus* are rather weak bearers. *Onchorynchus keta* and *Salverinus pluvius* lay submerged eggs under the river bottom. Most of the young

fish show negative phototropism and during their early stages they are found hiding in sand or concealed by suitable objects.

In order to encourage the increase of fishes found in the middle waters of a river, two principle methods must be applied. The first is the enlargement of their favorite environment and the second is a more primitive method of propagation.

The first method has long been carried out in England and has been used in America since about 1930 when C. L. HUBBS, the staff of the Scrip's Oceanographical Institution of California University and others started building dams, changing water courses and supplying places by means of artificial cover.

The building of dams for the purpose of ensuring suitable spawning place and supplying cover has been done for *Tribolodon hakuensis* in Japan but charging water courses has been attempted and further more we doubt whether the result would bring success in a country like Japan where the water runs rapidly.

Fish reservoirs must be provided with ascending canals ("Gyotei" in Japanese) in order to ensure free passage from outside.

The next consideration is to select suitable species for the reservoir and such place where the water currents are gentle. *Gnathopogon elongatus caerulescens*, *Chaenogobius isasa*, *Hypomesus olidus*, *Onchorhynchus nerka*, *Cyprinus carpio* and *Carassius auratus* are known to be suitable for this type of situation.

The second and more positive method of propagation is the protection of the natural breeding place and the encouragement of artificial hatching and transplanting from other areas.

Artificial hatching has not been tried on many kinds but M. TAUCHI experimented in Chikuma river in Nagano Prefecture with *Cyprinus carpio* and *Onchorhynchus masou* and obtained a survival record of 40% for the former and 20% for the latter.

In order to transplant fish many precautions must be taken. We do not have sufficient published material to propose such a project. We must therefore study the ecology and adaptability of the fishes and the fauna of the neighboring rivers.

Cobitis carinata of the mid-river section of Nagaragawa and Ibigawa in Gifu Prefecture live in a somewhat rapid current which has underflows. The distribution of this is fairly restricted by the physical condition of the river in Nagano, Yamanashi, Toyama, and Ishikawa Prefectures may prove to be a success.

Lastly we have consider the varieties of fish to select. We have the following successful records. The Fisheries Experimental Station of Gifu Pre-

fecture obtained a hybrid between *Onchorhynchus masou* and *O. rhodurus*.

This new hybrid is a land locked form with rapid growth than *O. masou*. We are now investigating the races of the Crucian carps, *Carassius auratus* to determin their habitat in order to obtain fast growing hybrids. It is also important to study the characteristics of trout hybrids between the native and imported species from America.

From the considerations stated above we are to proceed with our researches on the propagation of mid-river fishes.

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STUDIES ON THE DELPHINIDAE OF JAPAN (IV)

NOTES ON THE MIGRATION AND FOETUS OF *Phocaenoides dalli* (TRUE) IN JAPAN

(*With One Plate*)

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Two allied species of *Phocaenoides* are found in the Japan waters. *Phocaenoides Truei* (called "Rikuzeniruka" in Japan) is distributed in the northern region of the Pacific coast of Japan and migrates twice yearly. Its northward spring migration begins in February from off Chôshi, Chiba Prefecture to the Kurile Islands. The autumn migration from the Kurile Islands southward to off Fukushima Prefecture, or off Chôshi, Chiba Prefecture, begins in September.

The other species *Phocaenoides dalli* (called "Kitairuka" or "Ishiiruka" in Japan) is found mostly in the Japan Sea. It is observed off Tajima, Hyogo Prefecture from the end of February to the middle of March and in the middle of June off Akita Prefecture and from the end of June to the beginning of July along the Hokkaidô coast. They have occured in Okhotsk Sea in July and August and disappeared at the beginning of September. They probably go down to the southern part of the Japan sea in the autumn. Like other mammals, both species have a definite breeding season. In *Phocaenoides dalli*, this season is thought to be during the end of June and the beginning of July and of about one month duration. The reason is for this conclusion is that most of the female specimens of the present species collected in August in the Okhotsk Sea were found to be carrying small embryos of about 5.5 mm. in body length. The copulation therefore must have occured in August before this season. The gestation period is thought to last from seven to nine months because the adults with embryos of 5 mm. body length were caught commonly in the Okhotsk Sea during the summer from June to August, while the adults caught off Tajima, Sea of Japan during March and April had either already given birth or had a large foetus of about one meter body length.

In 1894, GULDBERG mentioned various foetuses of *Phocaenoides communis* measuring 7, 17, 18 mm. in body length, preserved in the Bergens Museum in

Norway. During 1889 to 1893, KÜKENTHAL also mentioned the embryos of *Lagenorhynchus* measuring 25 mm. in body length, preserved in the same Museum.

During the summer of 1943, and 1944, R HAYASHI, one of the authors, collected many embryos of *Phocaenoides dalli* at Abashiri fish market in Hokkaidô. They are excellent series of foetuses, the smallest one is 5.5 mm. and the largest 82 mm. in body length.

One embryo of 12 mm. body length, shows the most important features of the embryonic stage found in our collection. It may be described as follows.

The embryo head rather small, somewhat curved dorsoventrally about 90 degrees for the body axis. The fossa rhomboidalis behind the head is distinctly observed from the body surface. The abdominal side is nearly straight, while the dorsal side is somewhat curved. The tail is rather well developed, strongly curved inward, reaching the abdominal side of the face at the end. The divisions of head, trunk and abdomen are rather indistinct. The embryo indicates the early development of facial formation; the frontal furrow separating the cranium and facial portion is not yet differentiated. The frontal nasal process appears near the mouth on both lateral sides, showing nasal pit. It is nearly triangular in shape and divides the nasal process around the nasal pit dorsoventrally and not inwardly and outwardly as shown in land mammals. This feature may be considered characteristic of Toothed Whale in its early stage.

Upper madibular process shows a distinct discoidal shape, covering partially the lower mandibular arch. The latter is comparatively broad, forming a narrow groove between the second lingular arch. The anlage of the outer auditory canal is recognizable near the ventral side of the first branchial slit are considered as the anlage of the outer auditory process.

In 1889–1893, KÜKENTHAL pointed out the anlage of the pinna in the embryo of *Lagenorhynx* of, 25 mm. body length, from the histological and anatomical observations, but GULDBERG could not observe the anlage from the outside of the embryos of *Phocaenoides communis* of 7, 17, 18 mm. body length and of *Lagenorhynx* of 26, 30 mm. in body length.

In the embryo of *Phocaenoides dalli* of 28 mm. body length and of *Prodelphinus caeruleo-albus* of 18 mm. body length, the anlage of the outer auditory process is unrecognizable.

The eye slit is not yet formed; the eye is separated from the upper mandibular process by the lacrymal groove, slightly concaved, the center slightly raised, margined by a black elliptical ring. The upper margin of the eye somewhat raised and from which the eye lid is considered to begin its

developement. The myomeres of the trunk are observed along the neck to the tail from the surface of the skin. The demarcation of the lateral plate and abdomen runs along the median line of the body parallel to the dorsal line from the base of fore-limb to hind-limb.

The fore-limb is somewhat flattened and rounded at the end. In the embryo of 30 mm. body length, it changes its form to a fin-like shape. The hind-limb short and somewhat developed. The orientation is quite the same as that of other mammals. It exhibits a rather degenerative condition from the beginning of the developement and is considered to appear only for short period and has disappeared in the embryo of 30 mm. body length.

Foetal band occupies nearly half of the abbomen. The genital process is observed to be small, projected from the base of the foetal band. The sex-differentiation of the genital process is recognizable in the embryo of 50 mm. body length.

In the embryonal stage of about 30 mm. body length, the tail decreases its curveture. It becomes shorter in length but it strengthened by lateral lobes and appears like the fin-like tail. In this stage, the nasal pits on both sides approach each other, forming one pit on the median upper surface of the head. The foetal hair begins to appear at the mandibular margin. The dorsal fin begins to develope in the embryo of 50 mm. body length. This embryo is considered to exhibit a very important stage of its development showing many embryological characters of this group. The characters are provided with somewhat smaller head for body size and with generative hind limb. The anlage of outer pinna and the unity of the nasal pits on the upper surface of the head are characterized in the present embryo, which may be considered corresponding to the land mammalian embryos of 4 to 5 weeks developmental stage.

Plate 1

Explanation of Plate I

1. Lateral view of foetus in 12mm. body length
2. Lateral view of foetus in 13 mm. body length
3. Dorsal view of the above foetus
4. Dorsal view of mandibular part of the face, showing nasal pit and nasal process of the above foetus
5. Foetus of 18.3mm. body length
6. Foetus of 28mm. body length with foetal hairs on the upper mandible
7. Front of the head of the above foetus
8. Lateral view of the foetus in 30mm. body length with rudimentary hind limbs and small auditory pit
9. Front of the head of the above foetus
10. Foetus of 66.5mm. body length with an anlage of dorsal fin
11. Foetus of 82mm. body length with very small auditory pit and fin-like fore-limb



OKADA and HAYASHI—*Studies on Delphinidae of Japan (IV)*

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A REVIEW ON THE MACRORHAMPHOSUS FISHES OF JAPAN

(*With five Text-figures*)

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The species of Macrorhamphosus fishes have been described from Japanese waters. They are *M. sagifue* and *M. japonicus*. The first was described as a new species by JORDAN and STARKS[1] from a specimen collected at Enoura, Suruga Bay. They considered *Centriscus* sp. of ISHIKAWA[2], which was procured from Kagoshima, as a synonym. Those two authors further remarked that *M. sagifue* has a slightly more slender body, smaller eyes and longer snout than *C. scolopax* collected from the Canary Islands and described by GÜNTHER[3] in 1861. The same authors also mentioned (in the same paper) the specimens dredged at Misaki and Enoura in Sagami Bay, by U.S. Fish Commission steamer "*Albatross*".

M. japonicus, was originally described by GÜNTHER in 1861, together with the description of *C. gracilis* LOWE.[4] At the end of his description of *C. gracilis* he proposed *C. japonicus* for the Japanese specimens by pointing out a difference in the dorsal second spine which is slightly shorter than that of *C. gracilis*. He further noted that *C. gracilis* closely resembles *C. scolopax* but differs from it by having a somewhat more elongated body, a much shorter spine, smaller scales and, a little longer dorsal second spine.

In 1902, JORDAN and STARKS revised the Japanese Hemibranchiate fishes and in this they considered *C. japonicus* as a synonym of *M. japonicus* on the ground that Günther's type was doubtlessly obtained at Misaki.

In 1903, JORDAN, TANAKA and SNYDER[5] listed *M. sagifue* and *M. japonicus* as being distributed from Tokyo to Nagasaki.

1) JORDAN and STARKS, 1902, Proc. Unit. St. Mus., XXVI, No. 1308, pp. 69-70, fig. 2.
2) ISHIKAWA, GH., 1897, Prel. Cat., p. 32.
3) GÜNTHER, A., 1861, Cat. Brit. Mus., III, pp. 521-522.
4) LOWE, 1839, Proc, Zool., p. 86—Trans. Zool Soc., III, p. 12.
5) JORDAN, TANAKA and SNYDER, 1913, A catalogue of the Fishes of Japan, pp. 103-104, fig. 78.

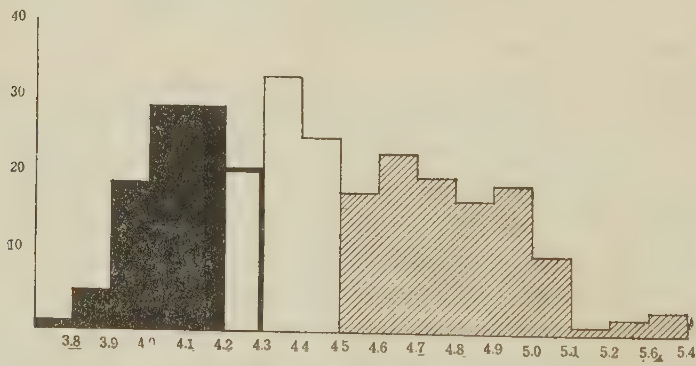
In 1921, OKADA, MATSUBARA and UCHIDA[6] published a book with illustrations entitled "Descriptions and Illustrations of Japanese Fishes" taking *M. japonicus* as a representative species of Family Macrorhamphidae found in Japan. In this the authors remarked that a *M. sagifue* is similar to *M. japonicus* only with the exception of its body length which is about four times more than its body height in the former species.

In examining a large number of specimens, it was found that most of them were *M. japonicus*, in general exhibiting smaller size than the typical specimen of *M. sagifue*. Further more it was found that the ratio of body length to height seems to vary according to age, because we noted individuals at intermediate of growth.

Based on specimens, taken in Japan, SH. TANAKA[7] considered *M. japonicus* and *M. sagifue* to be the same species.

By pointing out character differences found between *M. japonicus* and *M. sagifue* and also *M. gracilis* and *M. scolopax* UCHIDA[8] concluded that all those fishes are so closely allied that they should belong to but one species; but it was not stated whether such variable characters are the result of individual variations or phylogenetical types. Comparative analysis of the measurements of many specimens had not been taken.

When publishing "Description of the fishes from Prov. Tosa. and Kishyu,



Text-figure 1. Frequency of the ratio between the body height and body length. Black pattern indicates *M. sagifue*, the oblique line pattern indicating *M. Japonicus* and white one indicating an intermediate form.

6) OKADA, MATSUBARA and UCHIDA, 1921, Descriptions and Illustrations of Japanese Fishes, p. 92, pl. 35, fig. 4.

7) TANAKA, SH., 1931, On the Distribution of Fishes in Japanese Waters, Journ. Fac. Sci. Imp. Univ. Tokyo, Vol. III, part. 1, p. 20.

8) UCHIDA, K., 1935, Zool Mag., vol. 41, no. 563, pp. 645–651.

Japan" KAMOHARA[9] in 1950, listed two species of *Macrorhamphosus*.

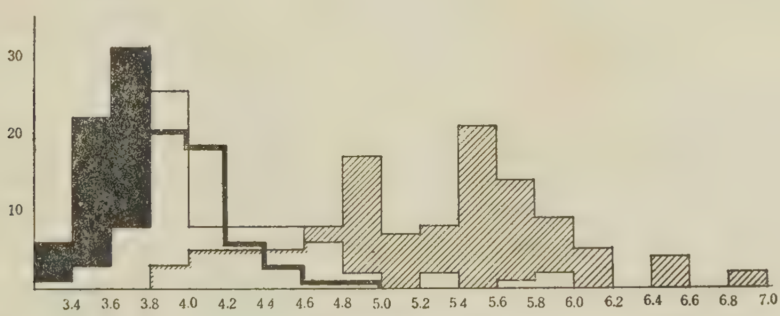
SMITH, J. L. B[10] published a monograph of the Marine Fishes from South Africa and described two species of the present genus *Macrorhamphosus gracilis* and *M. scolopax* with the synonymes *Centriscus japonicus* and *Macrorhamphosus sagifue*. He distinguished two species by the length of the second dorsal spine, remarking that the two species are closely allied.

The above is a brief historical sketch of the Japanese species of *Macrorhamphosus*.

During the survey of fishes in Mie Pref., the present authors had the good fortune of observing a fine series of 300 individuals of *M. sagifue* in the Owase Fish Market during 21-22, September and 15, October 1950. We are now able to discuss the affinity of the four species of *Macrorhamphosus* stated above.

Body height: *M. japonicus* and *M. sagifuc* are distinguishable by the different ratios of body height and length. After measuring 300 specimens, we found specimens intermediate between the two extreme groups as shown in text-fig. 1. As already noted by OKADA, MATSUBARA and UCHIDA, the slender form may be due to a young stage but the determination of age is necessary to settle this problem, and this may not be easy as these fish have placoid scales. From these facts, the above two names may be considered as but one species.

The second dorsal spine: The length of the second dorsal spine is variable in the series. *M. sagifue* is not always provided with a second dorsal spine which is longer than that in *M. japonicus*; other characters remain the same. (text-fig. 2.)



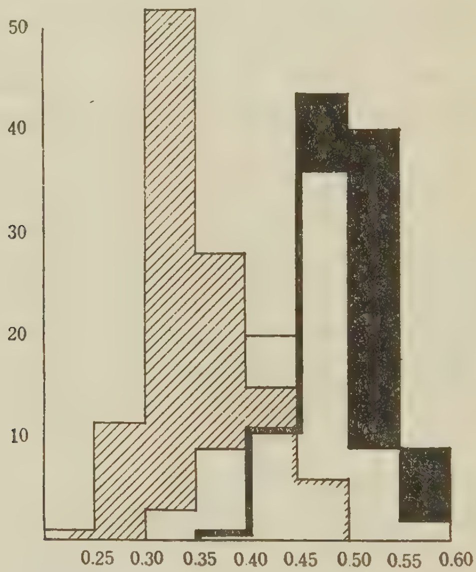
Text-figure 2. Frequency of the ratio between the length of second spine of the 1st dorsal fin and the body length.

9) KAMOHARA, T. 1950, Description of the Fishes from the Province of Tosa and Kishu, Japan, p. 68, fig. 58.

10) SMITH, J.L.B., 1949, The Sea Fishes of South Africa, pp. 171-172, fig. 363.

Comparison of *M. japonicus* with the European *C. gracilis* GÜNTHER[2] differentiationed between the two species according to the length of the second dorsal spine; *M. japonicus* has a shorter one than of *C. gracilis.*

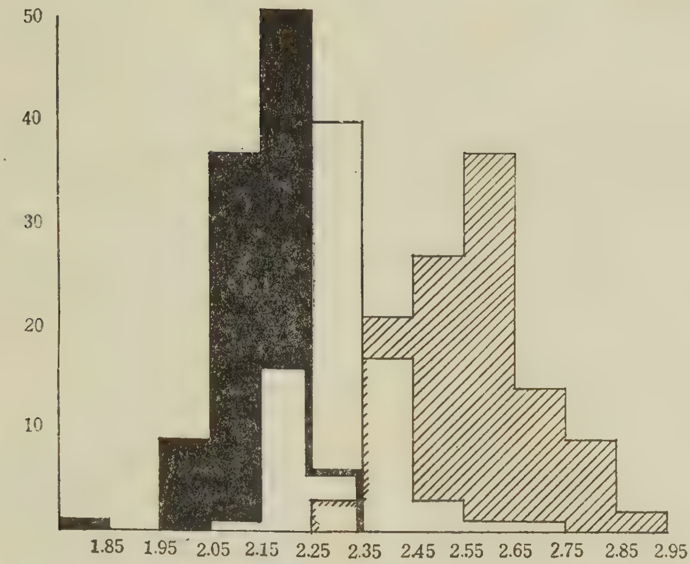
Measurements by us of the opercle from caudal in *M. japonicus* gives the ratio of 0.20--0.50 (Mode 0.325), whereas the length of the second caudal spine in the two species offer the ratio of 0.25--etc. 0.22 ($\frac{1}{4}$, $\frac{2}{9}$) as given by GÜNTHER. (text-fig. 3)



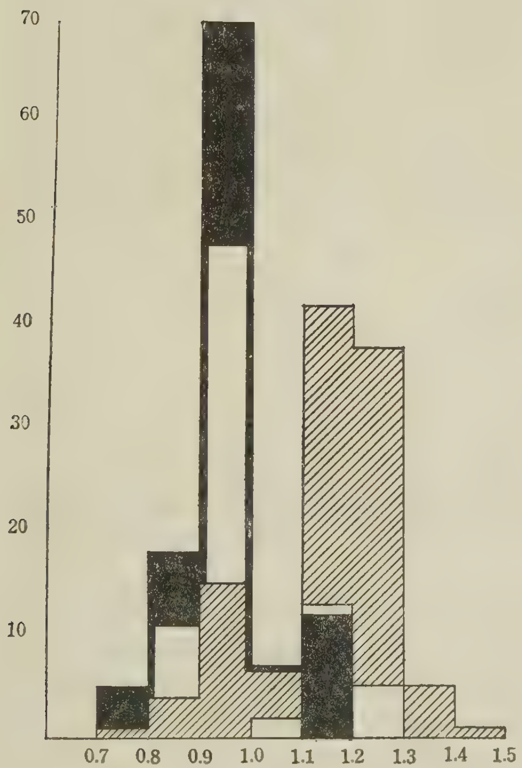
Text-fig 3. Frequency of the ratio between the length of the second spine of the 1st dorsal fin and the distance from the base of caudal fin to the posterior margin of opercle.

Comparison of *M. sagifue* with the European *C. scolopax*; Compared to *M. sagifue*, *C. scolcpax* has a more slender body, smaller orbit and longer snout. The ratio of the distance from opercle to caudal and body height in *C. scolopax* given by GÜNTHER is 1.65–2.33 ($1\frac{3}{4}$, $2\frac{1}{3}$) while that of *M. sagifue* taken by us is 1.75--2.35 (mode 2.2) In size of orbit, the ratio of the length of post-orbital part and the diameter of eye, is 1.0 in *C. scolopax*, as stated by GÜNTHER. In our series of *M. sagifue*, the ratio of eye size is 0.7–1.2 (Mode 0.95) (text-figs. 4. 5.)

By analysing the many characters proposed by various authors as given above, we have come to the conclusion that the supposed four species are to be united into one and it may be known as *Macrorhamphosus scolopax* (Linn.).



Text-figure 4. Frequency of the ratio between the distance from the posterior margin of opercle to the base of the caudal fin and the body height.



Text-figure 5. Frequency of the ratio between the length of postorbital part and the diameter of eye.

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ON TWO NEW SPECIES OF THE FAMILY APSEUDIDAE FOUND AT SETO

(*With 6 Text-figures*)

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The two new species of the Family Apseudidae, *Synapseudes setoensis* and *Metapseudes albidus* which are described here were found by myself from the intertidal zone on the rocky coast at Seto, Wakayama Prefecture. Algae or sessile animals taken from the rocks were washed out within a vessel containing sea-water, and by examining the debris remaining on the bottom numerous specimens of these species together with other Tanaids were easily collected. *Synapseudes setoensis* is very interesting because the chelae of the mature male are asymmetrically developed and the larger one is structurally different from the chela of the young specimens. This offers another example of the phenomenon of "high and low dimorphism" discovered by G. Smith in 1905. The other, *Metapseudes albidus* is the second species of the genus *Metapseudes*. In both of them, the female appears to show somewhat more frequent occurrence than the male.

Synapseudes setoensis n. sp.

(Figs. 1—3)

Habitat: Among barnacles on wave-swept open rocky coast.

A dimorphism is found in the gnathopoda of the male and female.

Female: Depressed, somewhat shorter than usual, 2.0 mm long and 0.44 mm wide. Integument thick and whitish except having brownish black color-patterns on the carapace.

Carapace a quarter as long as the body, longer than wide, quadrangular, but slightly narrower anteriorly than posteriorly. Anterior margin produced on the median in a trapezoid rostrum, which shows a frontal excavation, and curved angularly at the lateral corners. Lateral and posterior borders very slightly convex. Eye lobes distinctly pigmented and coalesced with the carapace

at the base. A single seta present on each side of the carapace about its middle.

Pereion about two thirds as long as the body. Second and seventh pereiomeres (first and sixth free somites) equal in length to each other and shorter than the others; fourth longest, being about one and half times longer than the second; length of others intermediate of these and subequal to one another. All are of the same width except the somewhat narrower seventh. Second pereiomere attached closely to the carapace, while the others are discontiguous as each is connected to the next anterior somite by a short median



Fig. 1. *Synapseudes setoensis* n. sp. a, dorsal view of female; b, lateral view of same; c, lateral view of male. a, b ×31; c ×33.

neck-like part. Each pereiomere has a longitudinal linear elevation interior to either margin, and bears four setae, one on each margin and one on each side of the midline, these forming a transverse row across the anterior part of each somite. Last somite with two lateral setae on either side. Coxal plate fused with the somite in all pereiomeres and invisible from the dorsal view.

Pleon short, nearly a seventh of the body, and composed of only three somites. First two of these three quarters as wide as the last pereiomere, transversely linear having rounded sides and with two to three pairs of dorsal

setae. Pleotelson much longer but slightly narrower than foregoing two, cordiform, ending in an obtuse point, and setose on the surface as well as on the margin.

Antennule as long as the carapace, extending forwards and biramous. First four joints of peduncle very thick and long so as to compose a half of the entire antennular length and denticulate along the inner border, second two fifths asg lon as the first, and the third and fourth succesively shorter and thinner. Flagellae very short, only slightly longer than the fourth joint of the peduncle; the outer member composed of three joints and the inner of two. All of the peduncular as well as the flagellar joints more or less setose and the apical joint of each flagellum bearing sensory setae besides ordinary ones. Antenna six-jointed, not extending beyond the first joint of the antennule, and lacking the scale. Basal joint enlarged, serrated and ciliated on the inner border, second to fourth smaller, sparsely setose, and the terminal two very minute being tipped by two long setae. Epistome armed with a strong spine. Labrum slightly bifurcated and with a tuft of setae on either lateral side. Mandible has a columnar molar process, an incisor process undivided on its edge and four or five setiferous spines beneath this; a lacinia mobilis present only on the right. Apical joint of the mandibular palp much shorter than the two basal cylindrical joints and bearing two spinulate setae of unequal lengths. Labium has a narrow spine-tipped movable lobe and a bifurcated accessory one inside this. Inner lobe of maxillula oval, bearing five ciliated spines on the distal margin and the outer lobe with nine or ten teeth; palp undiscovered. Maxilla composed of four lobes distinct from one another at least at their apical parts; outermost lobe with four spinulate spines, next one with two of such ones besides a simple one, others larger bearing six spinulate spines, but fourth lobe provided further with a simple spine on the outside and two very short ones on the inside. Basis of maxilliped not expanded at its base and with plumose spines and fine ciliae along the distal margin of its endognath. First joint of palp short, produced outwards; second large, lamellar, other two successively smaller, and all of them except the first fringed by two rows of long spines along inner margin; first joint with a single long spine respectively on the outer and inner angles and the second with an external spine also. Epipodite is a curved lappet having a narrow spine-like termination and thickly ciliated margin.

Right and left gnathopoda similar in size and structure, robust, with joints arranged in a twisted row, and both lacking the exopodite. Basal joint is composed by fusion of basis and ischium and makes a right angle with the small, narrow merus so as to hold between them the proximal part of the triangular carpus. Each of these joints bears a seta near the distal end of its free

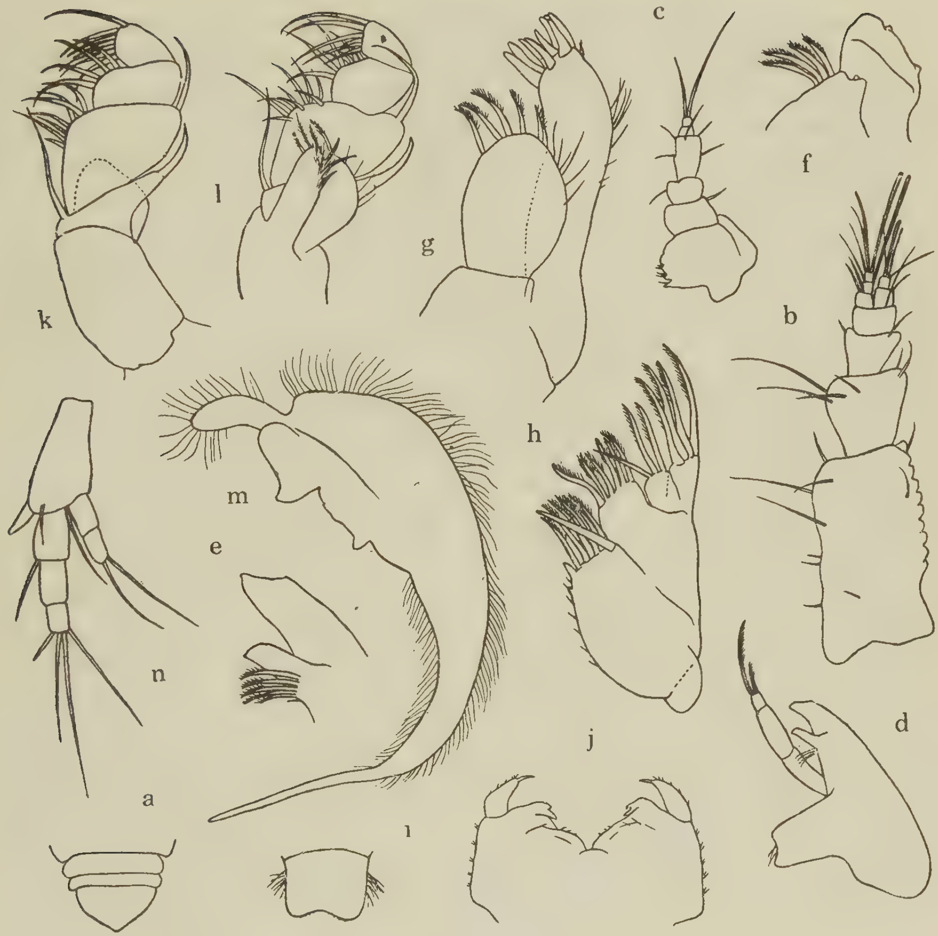


Fig. 2. *Synapseudes setoensis* n. sp. Pleon and appendages of female. a, pleon; b, antennule; c, antenna, viewed from inside; d, right mandible; e, incisor process with lacinia mobilis of same; f, incisor process of left mandible; g, maxillula; h, maxilla; i, labrum; j, labium; k, maxilliped; l, same, viewed from inside; m, epipodite of maxilliped; n, left uropod. a ×41; b, c ×123; d, i–l, n ×180; e–h, m ×350.

border. Propodus perpendicular to the carpus, twice as long as its own width, and forming a large, strong chela together with the curved dactylus. Cutting part of the chela half as long as the palm, with the two fingers terminating in a black, horny tooth. Three flattened, forked spines, besides a few setae, are present at the end of the cutting edge of the immovable finger, a long seta respectively at the base and on the outer border, and a row of fine hairs on the movable finger along its inner margin. Succeeding pairs of pereiopoda ambulatory, with basis and ischium fused together. Second pereiopod has joints broader than in others and lacks the exopodite. Its basi-ischium bears

three spine-like, pointed tubercles along the upper border and the merus has a spine at the dorsal angle of the expanded distal part and three at the ventral angle. Carpus and propodus possess two dorso-distal spines and a row of low tubercles along the distal border, besides a ventral spine-row consisting in the former of two and in the latter of four. Dactylus much narrower than other joints, unguiculate. Each joint sparsely setose and in addition has a long seta at the ventro-distal angle in the basal two joints, and at the dorso-distal angle in the other two. Third and fourth limbs resemble the second in number and arrangement of spines, but the former differs in having a single dorsal spine on the carpus, and the latter in the possession of three additional ones on the outer surface of this joint and three instead of four along the ventral border of the propodus as well as in lacking the ventral spine on the merus. The fifth has neither dorsal tubercles on the ischium nor a dorsal spine on the merus, but bears a short ventro-distal spine on the latter joint. Carpus with two spines on the ventral border, two on the distal border of the outer face, and three on the inner side. Propodus with two ventral spines and a number of thinner setiferous ones at the distal end. In the last two pereiopoda the basi-ischium spineless, the merus bearing one spine at the dorso-distal angle, the propodus with one and two respectively at the same angle and on the ventral border, and the carpus with a short ventral spine besides having two dorso-distal ones on the sixth limb only. A voluminous marsupium is formed by the imbrication of a single pair of large oostegites issuing from the bases of the fourth pereiopoda. In the non-ovigerous female, however, they are found as four pairs of rudimentary lobes attached to each pair from the second to the fifth pereiopoda inclusive.

Pleopoda absent. Uropoda as long as pleotelson, biramous. Its unjointed peduncle provided with a spine at its inner extremity; endopodite nearly as long as this, three-jointed and the exopodite shorter, two-jointed, both being setiferous at their apices.

Male: Although the gnathopod of the immature male resembles that of the female in structure, its size is more or less different between the two sides, this asymmetrical development being somewhat less conspicuous in smaller individuals. In the sexually mature male, the gnathopod of one side (either right or left) attains an enormous size and is structurally quite different from that of the other side which has ordinary construction. Carpus of larger gnathopod nearly as long as wide and more or less rhomboid in shape. Palm of chela much expanded, two fingers thick, showing a strong concavity on their inner edges so as, when closed, to leave a round space between them. Movable finger provided with several tubercles besides a few hairs along the cutting edge, and the immovable one with a patch of setae at the tip as well



Fig. 3. *Synapseudes setoensis* n. sp. External view of pereiopoda taken from the right side of female (except where indicated). a, gnathopod; b, chelate part of same, c, gnathopod of fully adult male (larger member of the pair); d, right gnathopod of younger male (larger member); e, pereiopod II; f, IV; g, V; h, same (inner face); i, VII; j, same (inner face). c, ×90; a, e–j ×123; b ×176.

as near the base. A pair of genital papillae present on the sternum of the last pereiomere. Otherwise no differential characters between the two sexes.

Remarks: The genus *Synapseudes* is hitherto known from three species: *heterocheles* (VANHÖFFEN), *minutus* MILLER, and *intumescens* MENZIES. The new species resembles most closely the first of these, which was reported from a locality near the South Pole, in general characteristics and above all in the

similarity of the gnathopoda. The resemblance is so pronounced that, if the two had come from very near localities, they would be united in one species, *heterocheles*. The gnathopod of *setoensis*, however, possesses a comparatively larger chela, which has a well-curved immovable finger, and lacks tubercles on the inner margin of the carpus and merus. Proximal joints of the second antenna are shorter than in *heterocheles*, the uropod has an exopodite composed of two joints instead of one, and the pereiopoda are somewhat different in the arrangement of the spines. Differences from the other species are larger. The present species can be distinguished from *intumescens* by the coxal plates being unseparable from the somites, by the constitution of the pleotelson, by the two pairs of antennae showing a lighter serration on the peduncle than in this species, and by the female chela which has no tubercle on the immovable finger. It differs from *minutus* in the shape as well as in the smaller size of the pleotelson and in the number of joints constituting the rami of the uropod and of the antennule. In the present species, the uropod has a two-jointed exopodite and a three-jointed endopodite, while these are one- and two-jointed respectively in *minutus*. The outer ramus of the antennule of the former is composed of three joints and the inner of two, but one more joint is added to both of them in the latter. Asymmetrical development of the chelae appears to be one of the characteristics of the genus *Synapseudes*. In *minutus*, and in *intumescens*, however, this does not appear to attain such an extent as to include a difference in structure between the right and left chelae.

Metapseudes albidus n. sp.

(Figs. 4–6)

Habitat: Among algae, on surfaces of sponges and compound Ascidiae growing over rocky coast.

A dimorphism is found in the gnathopoda of the male and female.

Female: Depressed, elongate, more attenuated posteriorly than anteriorly, 2.87 mm long and 0.66 mm wide. Integument rather thick, whitish and without pigment. Surface of the somites covered by ridges or swellings exhibiting as a whole an uneven appearance.

Carapace a quarter or fifth as long as the body, a little wider than long and slightly attenuating anteriorly. Front forms a crescent plate half as wide as the carapace, produced in an acuminate spine-like process on the median and margined by minute tubercles. Ocular lobe triangular, separated from the

carapace by an oblique border on either side of the frontal plate, and distinctly pigmented. Lateral border somewhat undulating, with a light concavity a little behind the ocular lobe. Dorsal face raised along midline in a broad longitudinal elevation. On each side of this and immediately behind the ocular lobe is a low swelling which is followed by another larger, perhaps higher one. Posterior region traversed by a transverse ridge, while the frontal area is depressed. Epistome with a short blunt spine.

Pereion two thirds as long as the body and gradually narrower from



Fig. 4. *Metapseudes albidus* n. sp. a, dorsal view of female; b, lateral view of same. ×30.

front backwards, last somite being three quarters as wide as the second (first free somite) which has the same width as the carapace. Third to sixth pereiomeres subequal in length and the others somewhat shorter. In the second pereiomere the two sides nearly parallel to each other though curved. These become inclined postero-internally in increasing degree towards the posterior

somites where these together with the hind border form a continuous convex curve. In accordance with this change, the point corresponding to the antero-lateral angle of the second pereiomere becomes displaced gradually backwards in the succeeding somites, so that a free border develops between this angle and the part articulating with the foregoing somite in each segment. Thus, the first three free somites are quadrangular, having the lateral region slightly produced back, fourth nearly trapezoid, and the last two hexagonal, either side projecting as a round tubercle. Surface of pereiomeres raised in a number of elevated areas bordered from one another by indistinct grooves. These areas are more distinct in the anterior part than in the posterior in every somite, and higher in the posterior somites so as to develop into conspicuous tubercles. Coxal plate distinctly separated in all pereiomeres with the exception of the second. It occupies a greater part of the free margin as a narrow crescent plate in the third and fourth somites, but is an oval one hanging on the postero-lateral border in the last three.

Pleon one sixth or seventh as long as the body, six-segmented. Pleomeres narrow, very short, highly convex above and with a small tubercle on either side of the midline. Lateral part drawn out in an acute process which bears a short seta on the third and fourth somites and a long one on the fifth. Pleotelson as long as the five pleomeres combined. It has a triangular process bearing short hairs on each side close to the anterior extremity and a setae-tipped, prominent tubercle interior to this. Two sides divergent posteriorly and making a right angle with the slightly convex posterior margin. The latter produced on the median in a long process pointing postero-dorsally and bearing a pair of long setae close to its base.

Antennule biramous, somewhat longer than the carapace, and bending down from the second joint in the natural status. The stout basal joint composes almost half the entire length of this appendage, sparingly hairy on the outer border and with two terminal spines, one on the inside and the other on the outside. Second joint much shorter and narrower, provided with a crown of setae around the distal border and a small spine on the inner side. Third joint surmounted by two filiform rami. Outer ramus four-jointed, as long as the two distal joints of the peduncle, the inner two-jointed reaching the penultimate joint of the outer, and both tipped by a bunch of setae. Antenna not extending beyond the peduncle of the antennule and composed of eight joints. Basal joint broad, with a number of denticles on the inner border, second produced distally on the same border in an acuminate process and bearing a small, narrow, setae-tipped scale on the outside; following joints much narrower than these two and sparingly setiferous. Molar process of mandible columnar, its distal end forming a striated triturating surface,

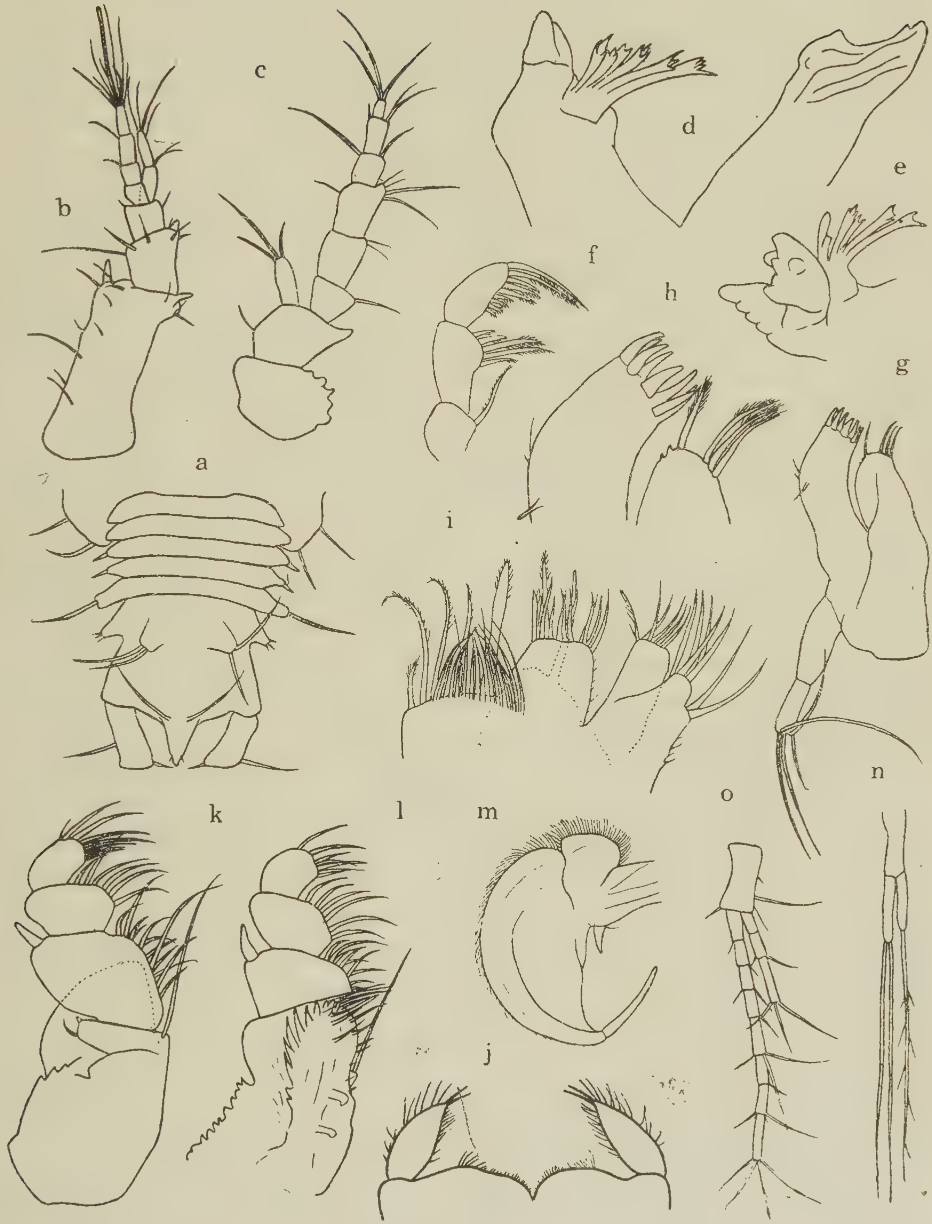


Fig. 5. *Metapseudes albidus* n. sp. Pleon and appendages of female. a, pleon; b, antennule; c, antenna; d, right mandible; e, incisor process with lacinia mobilis of left mandible; f, mandibular palp; g, maxillula; h, same, more enlarged; i, maxilla (viewed from inside); j, labium; k, right maxilliped; l, left maxilliped (inner face); m, epipodite of maxilliped; n, pleopod; o, uropod. a, b, o ×90; c, m ×123; f, g, j–l, n ×176; d, e, h, j ×346.

incisor process divided into a number of denticles and accompanied by a row of forked spines close to its base, lacinia mobilis, covered with many tubercles, present only on one of the mandibles. Basal joint of the palp terminating in a setiferous spine and the distal two joints fringed by a row of similar spines. Labium bilobed, finely ciliated on the margin and with a foliaceous, pointed, setiferous lobe which is movably articulated at either lateral end. Internal lamella of the maxillula has on its distal border three ciliated spines besides an outer solitary one, while the external lamella possesses eight to ten horny teeth. Palp filiform, two-jointed, and directed posteriorly, ending in a brush of several long setae. Maxilla composed of two indistinctly separated lamellae, each of which is subdivided into two lobes fringed by rows of numerous setae and long spines of various types. Basis of maxilliped serrated on the outer margin and bearing two retinacula on the inner side. Linguiform endognath beset with setae on the distal border and with a row of spines along the inner margin. First joint of maxilliped palp very short, bearing a very long seta on the inner side; second joint expanded, bearing a spine at the outer distal angle and followed by two successively smaller joints; inner margins of the second, third and fourth joints fringed by stiff setae. Epipodite attached to the base of the maxilliped by means of a slender stalk, semicircular, traversed by an incomplete line of articulation across the proximal part, and ending distally in a long spine; convex margin hairy, while the other margin non-hairy and with a short spine close to the origin of the stalk.

Gnathopod slender and without exopodite. Basis and ischium of this limb fused in an elongate-oval joint which is twice as long as wide and articulated with a small merus in the form of a V. Carpus elongate, a little longer than the basi-ischium and attached to the merus by the basal one third of its own ventral border. Propodus twice as long as wide, making an obtuse angle with the carpus; the part forming the immovable finger slightly shorter than the palm, ending in a tooth, and setaceous both on the outer and inner borders. Dactylus curved, attenuated towards the tip which bears a sharp claw, and a little setose on the inner edge. Second pereiopod with much flattened broader joints than in the succeeding limbs and armed with spines as well as setae; exopodite absent. Basis with a short spine on the inferior border at its distal end. Ischium very short, spineless. Merus with a spine respectively at the dorso-distal angle and on the ventral side somewhat proximal to its distal end. Carpus with two ventral spines, a dorso-distal one and another one of much smaller size on the outer surface near the base. On the propodus are four spines making a row along the ventral border and two of different size located on the dorsal border, the larger at the end and the smaller a short distance behind this. Small dactylus unguiculate. Other

pereiopoda somewhat poor in setae and with the basal two joints always spineless. Third and fourth pereiopoda similar to each other in structure. In both limbs the merus has a spine on the ventral margin a little below its end and another on the outer surface on the same level. Carpus possesses

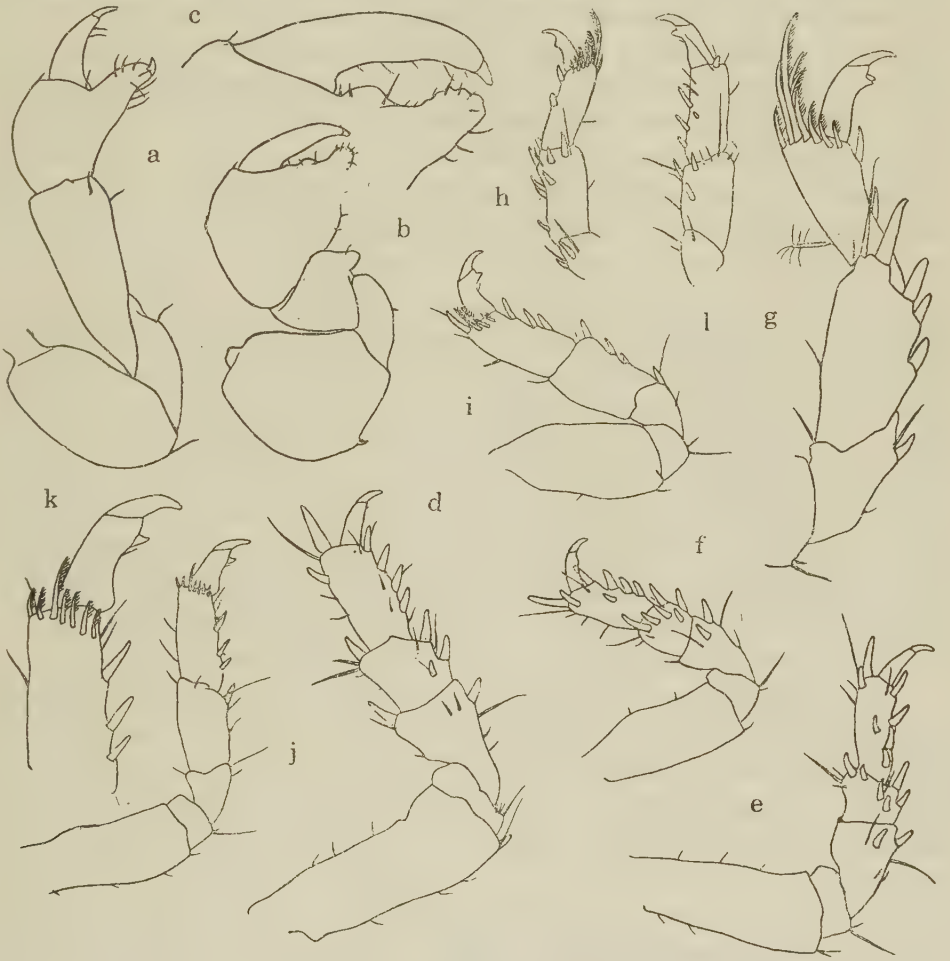


Fig. 6. *Metapseudes albidus* n. sp. External view of pereiopoda taken from the right of female (except where indicated). a, gnathopod; b, same of male; same (more enlarged); d, pereiopod II; e, III; f, IV; g, V; h, same (inner face); i, VI; j, VII; k, terminal part of same (more enlarged). b ×45; a, c–f, h–j ×90; g, k ×176.

four spines on the outer face arranged in a line extending from the supero-distal angle to the infero-proximal angle, besides having two on the ventral border. Number and arrangement of spines in the propodus as in this joint

of the second limb, differing only in the possession of an additional spine in the middle of the outer face and a pectinate one on the distal border of the inner face. Merus of fifth pereiopod has a spine on the inner face instead of on the outer unlike that of the foregoing limbs. Spines on the carpus make two longitudinal rows along the ventral margin, each row consisting of four and extending to a point near the dorso-distal angle of this joint, both on the outside and on the inside. Ventral spines of propodus reduced to two, while more than ten pectinate spines of various lengths surround the distal border of this joint. Two small acuminate tubercles project side by side on the ventral margin of the dactylus just behind the terminal claw. In the sixth pereiopod the merus has only one spine on the ventral border and each of the following two joints has three on the corresponding border. Terminal spines of the propodus less numerous than in the foregoing limb, only one pectinate spine being present on the inside and three of the same type as well as a simple one on the outside. Seventh limb without a spine on the merus, but with one at the ventro-distal end of the carpus and two on its inner surface. Spines on the propodus consist of three on the ventral border, one on the inside near the middle, another on the same side at the distal end, and a terminal row of pectinate spines on the other side. On the last two pereiopoda dactylus bears a single tubercle. Marsupium extending along the entire length of the ventral surface of the thorax. Non-ovigerous female has four pairs of rudimentary oostegites arising at the bases of the second to the fifth pereiopoda; first three pairs freely projecting downwards, while the last directed inwards, closely adhering to the sternum of the somite.

Five pairs of pleopoda biramous, small, and filiform; exopodite with two very long setae, while the endopodite with one. Uropod longer than the pleon, having two long filiform rami; inner ramus composed of eight joints, two and half times longer than the outer ramus which is slightly longer than the non-articulated, columnar peduncle, and is three-jointed; all joints of rami setiferous.

Male: Gnathopod about one and half times larger than that of the female, having broader and stouter joints. Basi-ischium a little longer than wide, strongly curved on the inferior border which bears a small spine, and straight on the other border. Carpus much shorter than in the female, as long as wide and with a tubercle at the ventro-proximal angle. Propodus stout, nearly triangular, two thirds as wide as long and with an inconspicuous tubercle on the upper border; immovable finger broad at the base, rounded at its apex, covered by papillae and short hairs in the distal part of the cutting edge, and with a tubercle close to its base. Dactylus slightly curved, terminating in a small claw and sparsely setose along the inner border.

Remarks: Although the present species does not resemble much the type species *auklandiae* STEPHENSEN in general appearance, there will be no doubt in that the two are con-generic, since they lack the exopodite both on the gnathopod and on the second pereiopod and have five pairs of biramous pleopoda, this combination of the characters not being found in other genera. Of the numerous differences found between the known and the new species the followings are considered to be sufficient to distinguish between them. In *albidus* the carapace is produced into a broad rostral plate, while in *auklandiae* it has a narrower, truncate front. The pleotelson which is provided with processes in the former is without these in the latter having a round posterior border. The scale of the second antenna present in one is absent in the other, and the characters of the appendages are quite different between the two.

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SOME BOPYRID PARASITES FOUND ON THE DECAPOD CRUSTACEANS FROM THE WATERS ALONG MIE PREFECTURE

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(*With 8 Text-figures*)

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In one of my papers already published, I described a new Bopyrid, *Pseudostegias hapalogasteri* parasitic on *Hapalogaster dentata* taken from Mie Prefecture. The present contribution deals with four species: *Stegoalpheon kempi* Chopra, *Pseudione magna* n. sp., *Ps. nephropsi* n. sp., and *Mesocepon tosizimensis* n. gen. & n. sp. Of these, the first named species is recorded for the first time from Japan. The succeeding two are discovered from the deep waters, and one of them, *Ps. nephropsi*, is remarkable for infesting an Astacura Decapod, since such a case has not been recorded till now. The last one is a representative of a new genus.

Stegoalpheon kempi Chopra

(Figs. 1 & 2)

Chopra, 1923. Rec. Ind. Mus., vol. 5, pp. 462–467.

Parasitic in the branchial cavity of *Crangon rapax* (de Haan) collected at Tôsizima-Island. Three females each associated with a male.

Female: Flattened, much asymmetrical, with an oval outline, 9.3 mm long, and 10.0 mm wide. Color yellowish white, without pigment and eye; eggs yellow. Cephalon, seven thoracic and six abdominal segments distinct.

Cephalon two thirds as long as wide, nearly oval, and slightly bilobed. Anterior lamina narrow, produced on either side in a small dactyliform process. Antennule three-jointed. Antenna four-jointed, with the basal article presenting an appearance of a ridge on the ventral surface of cephalon. Palp of maxilliped short, oval, with ciliated margin. Posterior lamina has four lateral hooks on either side.

Thorax widest in the third segment. First two segments very short in

the mid-dorsal region. In these segments as well as in the succeeding three, posterior border has a semicircular bulge at some distance inside the lateral margin, which is distinctly bilobed. Last two segments without such a bulge and undivided on the margin. Coxal plates narrow, preesnt on the first four

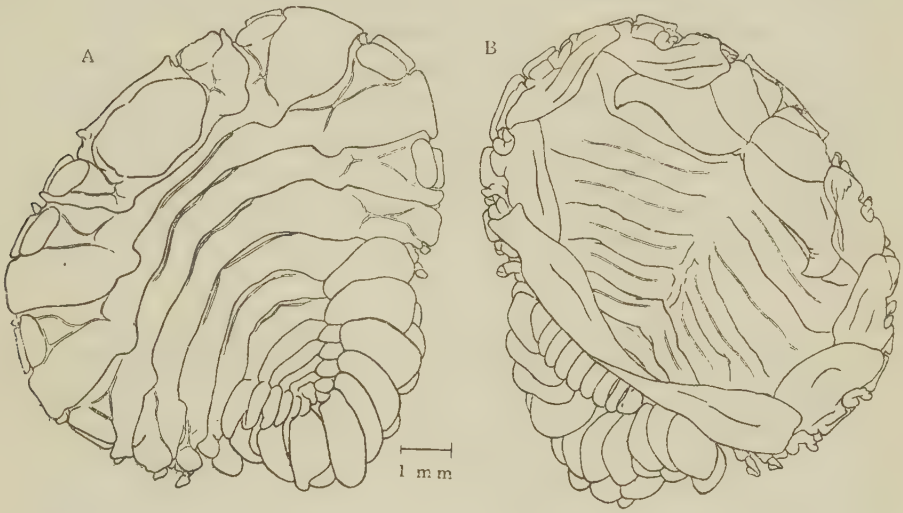


Fig. 1. *Stegoalpheon kempi* CHOPRA, female. A, dorsal view; B, ventral view.

segments, but highly degenerated in the first on the right. Oblong ovarian bosses also defined in these. Post-lateral lobes in the second and third segments strongly expanded surpassing their ovarian bosses in length. Those are much narrower in the fourth being nearly one third shorter than these. They are further reduced in the first into dactyliform lobes and almost rudimentary in the fifth. Marsupium widely open. First oostegite has posterior lamella produced backwards in an acuminate lobe and its inner crest entire.

Abdomen one third as wide as the body and one fifth as long. All six segments have a pair of crescent-shaped lateral plates which are attached by their broad base to either end of the posterior border of segment and freely projecting dorsally. These plates diminish in size little by little from before backwards. Pleopoda biramous, with the two rami oval, lamellar and extending laterally beyond segment margin. They become successively larger towards the posterior on the shorter side of body, while grow smaller though slightly on the other side. Uropoda uniramous, large and lamellar resembling pleopoda in appearance.

Male: Depressed, short, 3.05 mm long and 1.35 mm wide at the fifth thoracic segment. Whitish in color, but with a few scattered pigment patches besides eyes.

Cephalon semicircular, one and half times wider than long. It is distinct from the first thoracic segment and narrower. Antennule short, three-jointed. Antenna five-jointed, much longer, extending far beyond cephalic margin.

Thorax widest in the fifth segment, gradually narrowing both anteriorly and posteriorly. First segment four fifths as wide as the widest. All segments have round sides and a very slight bulge on the anterior border a short distance inwards from each extreme lateral end. First two pairs of pereiopoda have a chela broader than these of the succeeding limbs and in structure somewhat different from them. No medio-ventral tubercle.

Segments of abdomen consolidate in a semicircular piece. It is arched dorsally, but flattened ventrally, and has more or less undulated margin. Pleopoda and uropoda absent.

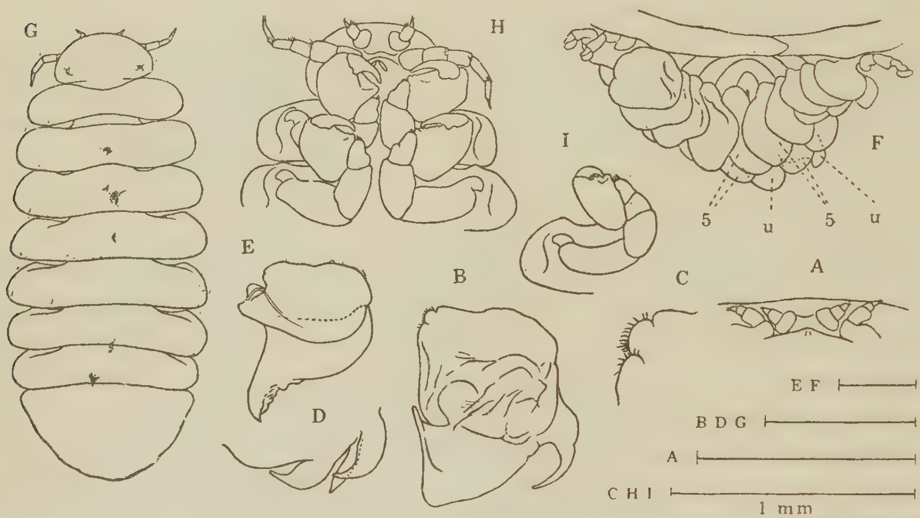


Fig. 2. *Stegoalpheon kempi* CHOPRA. A–F, female. A, two pairs of antennae; B, maxilliped; C, palp of same; D, lateral hooks of posterior lamina of cephalon; E, first oostegite of the right; F, ventral view of abdomen. G–H, male. G, dorsal view; H, anterior part of body, ventral view. u, uropod; 5, two rami of the fifth pleopoda.

Remarks: This is the first record of the species from Japanese waters. It was primarily described from India and, according to CHOPRA, was parasitic on a species of *Alpheus* closely resembling *A. crassimanus* HELLER. Japanese specimens are the parasite of a different host, *Crangon rapax* (DE HAAN).

Although there is no doubt in that the present specimens belong to CHOPRA's species, they show some points of minor difference. The cephalon of the female has a dactyliform lateral process on either side and is much

similar in its configuration to the cephalon of *Argeia lowisi* CHOPRA figured by NIERSTRASZ and BRENDER À BRANDIS (1929) rather than to that of *Stegoalpheon kempi* given by CHOPRA. Posterior lamina has four pairs of lateral hooks instead of two pairs. The first oostegite possesses a posterior elongation more sharply pointed than in CHOPRA's figure. Abdomen of the male is triangular in Indian specimen, the two sides being straight and converging backwards, but in Japanese ones it is semicircular with a round posterior border. The eyes present in the former are absent from the latter. Strange to say, the females of my specimens appear to bear a certain resemblance to *Argeia lowisi* rather than to *Stegoalpheon kempi* in general conspectus, but they have crescent-shaped lateral plates which are absent in *Argeia*. The abdomen of the males is quite different between the two forms, as this is more elongated and more attenuating towards the tip in *Argeia lowisi*.

As regards the three lamellae found on either side of each pleomere in the female, CHOPRA interpreted them as to represent a tripartite pleopod. Two horizontal lamellae are, according to him, endopodite and exopodite, and the vertical one the prolongation of protopodite. But, in my opinion, they are merely a biramous pleopod and a lateral plate. It appears to me natural to take his protopodite as lateral plate, since this third ramus is coalesced along its entire base with the post-lateral border of pleomere and never free.

Stegoalpheon appears to be very close to *Argeia* and *Parargeia*. If it were without lateral plates on the female abdomen, the definition of it would become identical with that of the latter genera. Further, the male has coalesced pleomeres in any of those three.

Pseudione magna n. sp.

(Figs. 3 & 4)

Parasitic in the branchial cavity of *Heterocarpus sibogae* DE MAN collected at a point off Owase, Province Sima. Three females and a male.

Female: Ovate, slightly asymmetrical, 20.2 mm long and 13.9 mm wide at the fourth thoracic segment. Dorsal side flat, ventral convex. Whitish, neither any pigment, nor that of eye. Cephalon, seven thoracic and six abdominal segments distinct.

Cephalon small, triangular, one sixth as long as the body, shorter than wide. Frontal border widely round, margined by a narrow anterior lamina. Two sides converging backwards and combined by the short, horizontal posterior border. First pair of antennae three-jointed, second four-jointed.

Maxilliped has a linguiform, setiferous palp. Posterior lamina bears two lateral hooks on either side.

Thorax widest in the third segment. First segment very short in the mid-dorsal region. Posterior borders of all segments with a slight bulge at

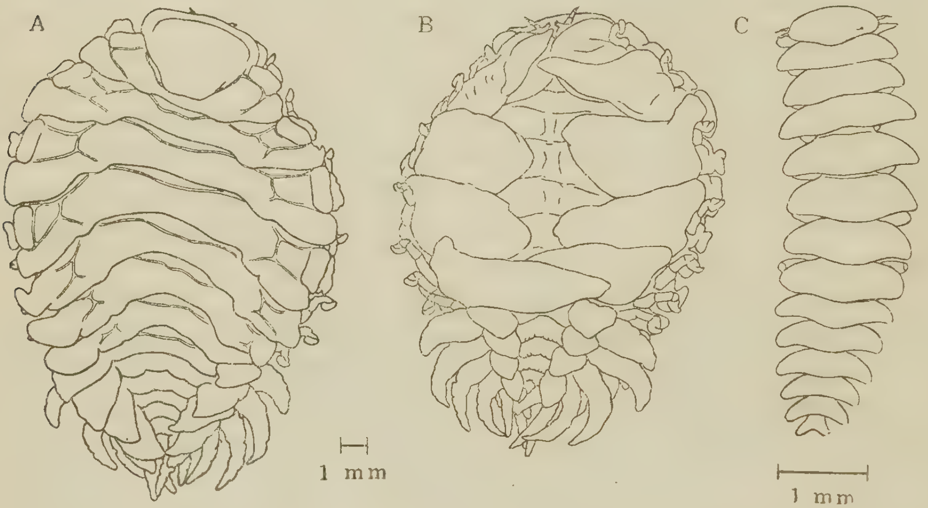


Fig. 3. *Pseudione magna* n. sp. A, female, dorsal view; B, same, ventral view; C, male, dorsal view.

a certain distance inwards from either lateral margin. First four segments bilobed in lateral parts. Anterior lobe is a little longer than posterior lobe and provided with an oblong ovarian boss and a narrow coxal plate having more or less irregular margin. Last three segments undivided in lateral region, but ending in a lobe somewhat constricted from the somite by a notch on the posterior margin. Marsupium highly vaulted, but a little gaping in a longitudinal central area. Right and left oostegites of first pair somewhat different from each other in general configuration. They have more or less digitated inner crest and their posterior lamellae possess a linguiform elongation which is broader and longer in the left member.

Abdomen slightly longer than a quarter of the body. First five segments arched anteriorly and with well-developed, triangular, foliaceous lateral plates. These plates, imbricating one upon another, direct backwards as well as somewhat inwards. Last segment very small, without them. Ventral border of all segments more or less rugose. Pleopoda biramous. Endopodite of all pairs of them nearly oval, directing postero-internally, but leaving the mid-ventral area of segments uncovered. Those of fifth pair alone much narrowed, taking lancet-form. Exopodites much longer than endopodites.

curved, lanceolate, and projecting externally far beyond lateral plates. Uropoda uniramous, resembling exopodites of pleopoda in appearance.

Male: Elongate, depressed, 6.0 mm long and 1.8 mm wide at the fifth thoracic segment. Whitish, without any pigment except a pair of small eye spots. All segments of body distinct.

Cephalon twice as wide as long, widely round in front, a flattened V-shape behind. Antennule short, two-jointed. Antenna longer, extending beyond cephalic margin, composed of four-jointed peduncle and a very thin three-jointed flagellum.

Thoracic segments slightly diminish in width from the widest fifth forwards, and have lateral part narrowing to a round end. Medio-ventral tubercle present in those segments at least from the third backwards.

Abdomen a little less than one third the body length, with six distinct segments. First five segments resemble those of thorax having narrowed lateral plates. Last segment bifurcates posteriorly. Pleopoda represented by five pairs of conical processes. Uropoda absent. Medio-ventral tubercle present at least in the first three segments.

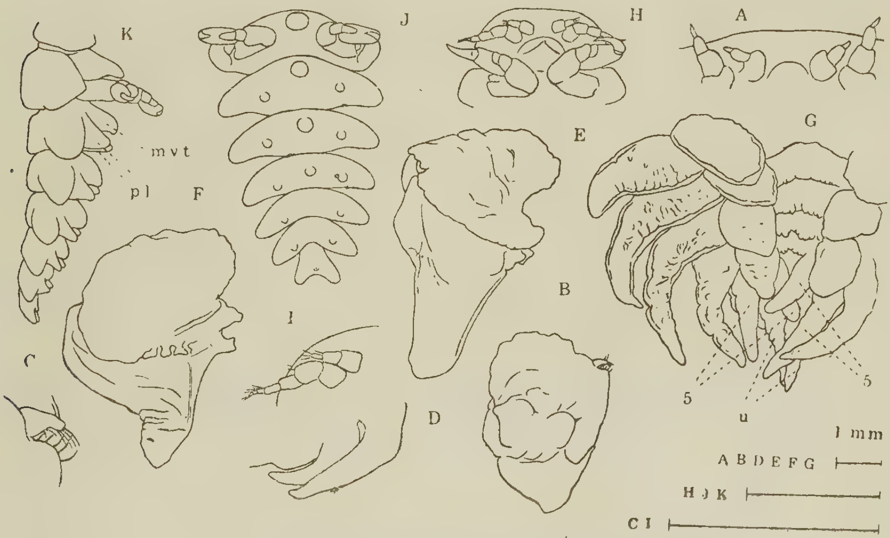


Fig. 4. *Pseudione magna* n. sp. A-G, female. A, two pairs of antennae; B, maxilliped; C, palp of same; D, lateral hooks of posterior lamina of cephalon; E, first oostegite of the left, outer view; F, same of the right, inner view: G, abdomen, ventral view, a part of the left half unindicated. H-K, male. H, cephalon and first pereiomere, ventral view; I, right half of cephalon, ventral view; J, abdomen, ventral view: K, same, lateral view. mvt, medio-ventral tubercle; pl, pleopoda; u, uropoda; 5, both rami of the fifth pleopoda.

Remarks: There may be no doubt in that the present species can be assigned to the genus *Pseudione*. It has very narrow coxal plates, biramous pleopoda and uniramous uropoda in the female and six distinct abdominal somites besides tubercular pleopoda in the male, all of these being the characters of this genus.

In the possession of well-developed lateral plates on the female abdomen, the new species is related more or less closely to *Ps. hyndmanni* (Bate & Westwood), *affinis* G. O. Sars, *crenulata* G. O. Sars, *hoylei* Giard & Bonnier, *upogebiae* Hay, *hayi* Nierstrasz & Brender à Brandis, *galacanthae* Hansen, *insignis* Giard & Bonnier and *dohrni* Giard & Eonnier. Unlike these species except the last three, *magna* has the endopodites of pleopoda somewhat round and far shorter than the exopodites. It is also different in the lateral plates being attenuated to the tip and directed postero-internally. Differences from the other species can also be found in the characters of those parts of body. In *galacanthae*, both rami of pleopoda as well as lateral plates are round, but in the present species these are acuminated towards the tip except for the endopodites. Lateral plates which extend postero-internally in the new species are projecting laterally in *insignis* and *dohrni*, besides the endopodites are round in the former and pointed in the latter two. Further, the male of *dohrni* has the last two abdominal segments entirely fused with each other.

The male of the present species is characterized by its bifurcated pleotelson. Such is also found in *elongata* (Hansen), its variety *normalis* Nierstrasz & Brender à Brandis and *laevis* (Richardson), but these are different from the present species in the shape of the female. Lateral plates are not so well developed in *laevis* as in *magna*, and are projecting laterally in *elongata*. Besides, the body of *elongata* is far more slender. At any rate, however, those species appear to be most closely related to the new species, especially on the point that their males are provided with well-developed medio-ventral tubercles. As the description given by Nierstrasz and Brender à Brandis on *normalis* is very brief, it can be said little with regard to the distinction between this and the new species. But, this may be sufficient to call attention on the difference in the configuration of the male pleotelson.

Pseudione nephropsi n. sp.

(Figs. 5 & 6)

Parasitic in the left branchial cavity of *Nephrops japonicus* Tapparone-Canefri captured at a point off Owase, Province Sima. A female and a male.

Female: With cephalon, seven thoracic and six abdominal segments

distinct. Only slightly asymmetrical, more or less ovate, 20 mm long and 12 mm wide at the third thoracic segment. Dorsal face flat, ventral strongly convex. No pigment, no eye.

Cephalon small, about a sixth as long as the body, and transversely oval, being wider than long. Anterior lamina very narrow, rudimentary, and not extending laterally beyond the width of cephalon. Antennule short, two-jointed. Antenna longer, five- or six-jointed, with the basal article fused with the ventral surface of cephalon in a form of ridge. Maxilliped has a squarish palp which is ciliated only on the apical margin. Posterior lamina bears a pair of lateral hooks.

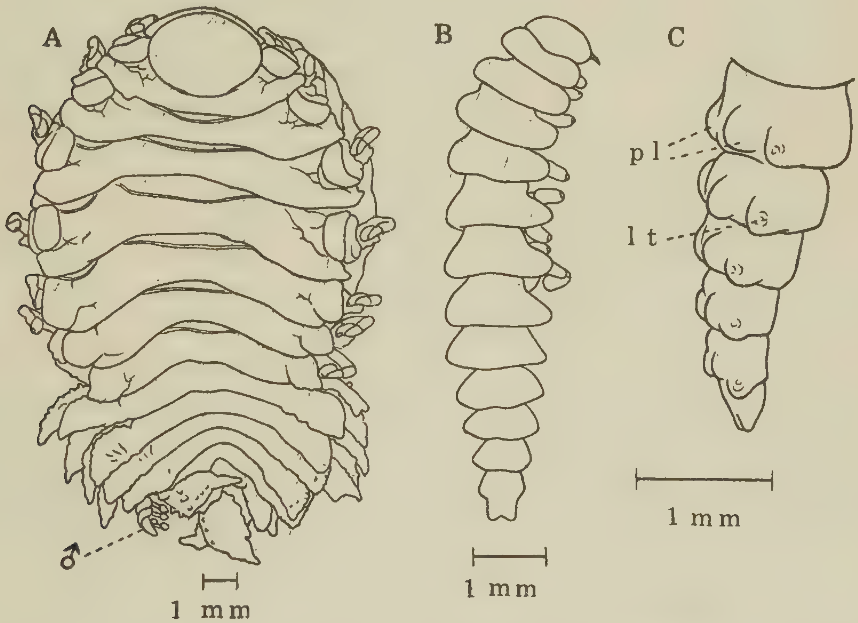


Fig. 5. *Pseudione nephropsi* n. sp. A, female, dorsal view; B, male, dorsal view; C, abdomen of same, ventro-lateral view. pl, pleopod; lt, lateral part of segment.

First four thoracic segments bilobed on either side. Anterior lateral parts longer than the posterior parts in all of them, and provided with narrow coxal plates as well as very low ovarian bosses. Lateral margin of last three segments is occupied by the former part, the latter part being much reduced and retreating from the general outline of thorax. Coxal plates and ovarian bosses absent in those segments except the fifth where a much rudimentary coxal plate is defined only on the right side. Pereiopoda more or less tubercular onl the surface of podomeres, and especially so on the basis.

Marsupium vaulted, nearly closed, though open in a small central area. First oostegite has the posterior lamella elongating in a short linguiform lobe, and the inner crest bearing some dactyliform tubercles.

First five abdominal segments have well-developed lateral plates. These are elongate, foliaceous lamellae, and strongly tuberculated on their ventral surface. Tuberculation is stronger along their free margin, but very feeble on the dorsal face, which becomes almost smooth in the anterior segments. Last segment triangular, having somewhat sinuous posterior border. It has a small oval lobe which represents probably a remnant of a lateral plate and arises from the left posterior angle of the segment with a narrow base. On the other side, it remains to issue a short dactyliform process. Ventral surface of abdomen rugose along the segmental borders. Pleopoda biramous, with the two rami tubercular on either surface as well as on free margin. Exopodites direct laterally extending a little beyond the lateral plates and diminish in size only slightly from before backwards. Endopodites much longer than these in anterior pairs, but rapidly shortening towards posterior pairs and projecting backwards. Uropoda similar in appearance to the pleopoda and more or less tubercular on the surfaces, but much longer than the fifth pair of these.

Male: Narrow and elongate, 7 mm long, 1.5 mm wide at the sixth thoracic segment. No pigment, no eye. Medio-ventral tubercle absent. All segments of the body except the last two distinct.

Cephalon about twice wider than long, widely round in front and a flattened V-shape behind. Antennule three-jointed. Antenna extending beyond the cephalic margin, six-jointed.

First thoracic segment contiguous with the cephalon. Succeeding ones discontiguous in their round lateral parts. Each of them has the median part projecting in front like a short neck by which it is articulated with the foregoing segment. All segments subequal in width except the first which is somewhat narrower.

Abdomen five-segmented. First four segments more or less trapezoid being wider on the posterior border than on the anterior. Configuration of the last segment clearly indicates that it is formed by the fusion of the trapezoid fifth and the quadrangular sixth which bears a median notch on the posterior border. Pleopoda present as five pairs of round tubercles, last pair of them locating on the anterior half of the terminal segment. Uropoda absent.

Remarks: With some hesitation, I assign the present species to the genus *Pseudione*. It has a structure which is believed to be a lateral plate on the pleotelson of the female though only on one side, and the fifth pleomere of the male is fused with the pleotelson. These points might be sufficient to distinguish it from other species of *Pseudione* as a representative of a new

genus. It is evidently an abnormality that the plate is developed only on one side, but not certain whether the female has this plate normally on both sides, or lacks it entirely. Until something further is known about this point, it is impossible to be sure of necessity for erecting a new genus for that character of the male alone.

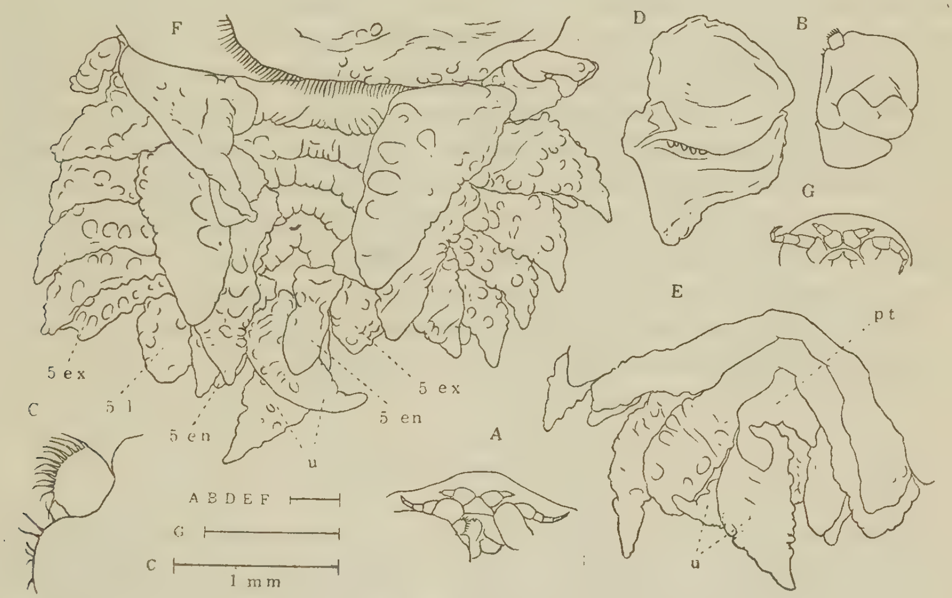


Fig. 6. *Pseudione nephropsi* n. sp. A–F, female. A, cephalon, ventral view; B, maxilliped; C, palp of same; D, first oostegite of the left, inner view; E, posterior part of abdomen, dorsal view; F, abdomen, ventral view. G, cephalon of male, ventral view. pl, pleotelson; u, uropod; 5 en, endopodite of the fifth pleopod; 5 ex, exopodite of same; 5 l, lateral plate of the fifth pleomere.

If the present species has a pair of lateral plates on the pleotelson, it becomes to show a certain resemblance to *Orbione*. This genus, however, possessing well-developed coxal plates, cannot include the present species. Admitting that the plate of pleotelson is to represent another ramus of the uropod, the new species lacks well-developed or abnormally expanded coxal plates which are observed in *Apopenaeon* Nierstrasz & Brender à Brandis or *Gigantione* Kossmann. *Munidion* Hansen and *Paragigantione* Barnard which have biramous uropoda are also different from the present species in having all the pleomeres of the male coalesced into one. *Pagurion* Shiino and *Parapagurion* Shiino are quite other things.

On the other hand, the present species resembles *Aporobopyroides* Nobili, *Parione* Richardson, *Parionella* Nierstrasz & Brender à Brandis in the fusion of the fifth somite with the last in the male abdomen. These genera,

however, have the lateral plates of the female quite rudimentary, unlike the present species. Despite this coalescence, the male of the present species is provided with the fifth pleopoda on the anterior half of the fused segment. The configuration of this segment also clearly shows the outline of the respective segments. Further, it must be mentioned that the male of *Pseudione dohrni* GIARD & BONNIER, which has the last two segments similarly fused together, possesses distinctly five pairs of pleopoda. The female of this species has well-developed lateral plates and tuberculated, foliaceous pleopoda as the present one. In these points, the two species are close to each other, but the configuration of the composite segment of the male is entirely different between them, besides the fusion being more complete in *dohrni*.

From these reasons enumerated, it appears to me appropriate to place the new species, for the present at least, in *Pseudione* inspite of the above-mentioned deviation from the original definition of this genus.

It is worthy to note that the present species offers the first instance of an infection of Bopyrid parasite on the Astacura Decapod.

Mesocepon n. gen.

Female has all somites of body distinct. Madio-dorsal process develops in fifth to seventh pereiomeres. Lateral plates foliaceous, present in first five pleomeres, but absent from the last somite. Pleopoda and uropoda lamellar and uniramous without any trace of endopodite.

Male has all somites separate. Each pereiomere has a medio-ventral tubercle. No pleopod, no uropod.

The new genus is more closely related to *Merocepon* than to any others, the two agreeing each other in the possession of medio-dorsal processes in the last three thoracic segments. But, they are different in the characters of the abdomens of both the sexes, since in *Merocepon* the female has well-developed endopodites on the pleopoda and the male is provided with five pairs of tubercular pleopoda.

Mesocepon tosizimensis n. sp.

(Figs. 7 & 8)

Parasitic in the branchial cavity of *Arcania undecimspinosa* DE HAAN taken at Tôsi, the Island of Tôsizima. A female and a male.

Female: With cephalon, seven thoracic and six abdominal segments

distinct. Slightly asymmetrical, elongate oval, 5.5 mm long excluding uropoda and 3.5 mm wide at the fourth thoracic segment. Dorsal surface concave, showing an antero-posterior curvature, but somewhat keeled along the median line, and ventral surface highly convex. No pigment, no eye.

Cephalon transversely oval, one and half times wider than long and about a fifth as long as the body. It is much swollen dorsally and bilobed in front. Anterior lamina moderately broad, having a somewhat irregular margin. First pair of antennae two-jointed, second pair longer, five-jointed, with a large, inflated basal segment. Right and left members of both the pairs widely apart from each other. Maxilliped has a long, narrow, curved palp which is ciliated along the margin, but is not separated from the main portion by any distinct border.

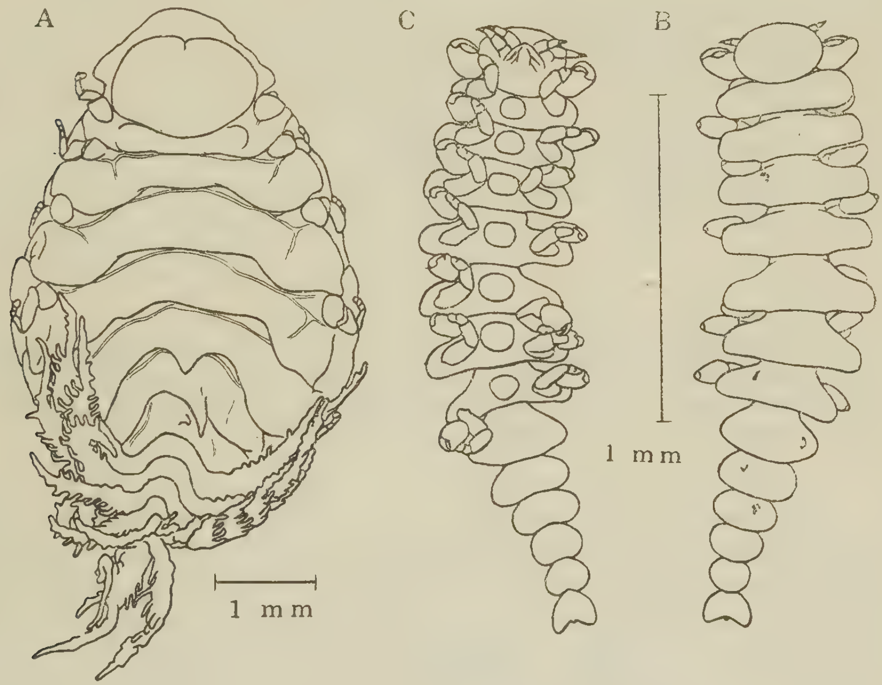


Fig. 7. *Mesocepon tosizimensis* n. gen. & n. sp. A, female, dorsal view; B, male, dorsal view; C, same, ventral view.

Thorax widest in the fifth segment, narrowing both forwards and backwards. First two segments much shorter than others in mid-dorsal region. These as well as the succeeding two segments bilobed in their lateral parts. Anterior lateral parts rather small, occupied by round ovarian bosses, and without coxal plates or with much rudimentary ones. Posterior lateral

parts shorter than the anterior parts in the first segment, but much expanded and swollen in others, occupying a greater part of lateral sides. Last three segments undivided on their margin, besides lacking both the ovarian bosses and the coxal plates. Medio-dorsal process present on each of these segments. It is short, broad at the base, curving back and tapering to a point

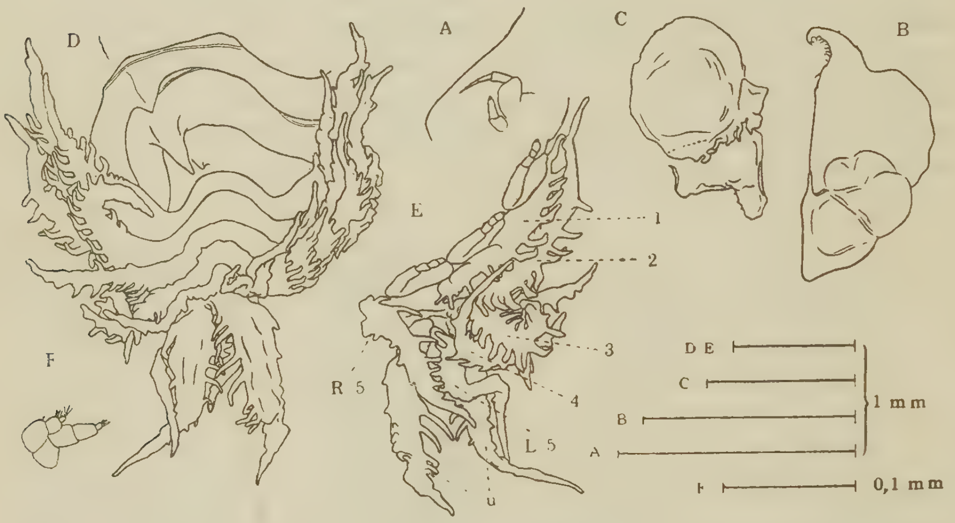


Fig. 8. *Mesocepon tosizimensis* n. gen. & n. sp. A–E, female. A, two antennae of the left in situ; B, maxilliped; C, first oostegite of the right, inner view; D, abdomen with posterior part of thorax, dorsal view; E, left half of abdomen, ventral view. F, male, two antennae of the left in situ. L 5, fifth pleopod of the left; R 5, same of the right; u uropoda; other numerals indicate the pleopoda in due order.

in the fifth segment, while longer, narrower, sharper and well-curved in the sixth. It is a very minute hook in the last. Marsupium vaulted and almost completely closed. Anterior lamella of first oostegite comparatively large, with digitate inner crest, and the posterior lamella far smaller, having a narrow backward elongation. Pereiopoda elongate and slender.

Abdomen small, a little less than a quarter of the body, with six distinct segments. First five segments rather narrow, but with elongate, narrow, foliaceous lateral plates. These are distinctly digitated around margin and freely projecting antero-dorsally. Last segment very small, without lateral plates. Five pairs of pleopoda uniramous, lacking any rudiments of endopodites. They are similar to the lateral plates in appearance in having digitate margin and in directing antero-dorsally. Uropoda also uniramous resembling pleopoda, but much larger and broader than the last pair of these.

Male: Slender, elongate, flattened dorso-ventrally. No eye, but with some scattered pigment patches on the body. Cephalon, seven thoracic and six abdominal segments distinct.

Cephalon two thirds as long as wide, transversely ovate. Antennule short, three-jointed. Antenna longer, extending a little beyond the cephalic border, five-jointed.

Thoracic segments discontiguous at the sides. Each of them is articulated with the foregoing segment by a short neck-like median projecting part, but separated in the lateral portion by a narrow space. First pair of pereiopoda somewhat larger than the succeeding pairs and with a more strongly curved dactylus. All segments with a more or less round medio-ventral tubercle.

Abdomen a little more than one third of the entire body. First segment resembles the last thoracic segment in having a short median projecting part, but with round sides. Succeeding four oval in shape and the last cordiform, having a bilobed posterior border. Pleopoda and uropoda undeveloped.

Remarks: As stated above, the new species is very close to *Merocepon* which has hitherto been represented by a single species *M. xanthi* RICHARDSON. The points of difference between this species and the one descrived above are tabulated as in the following:

		Merocepon xanthi	*Mesocepon toizimensis*
Female	Endopodites of pleopoda	present	absent
	Pleopoda and lateral plates	tubercular	digitate
	Ovarian bosses	enormous	small
Male	Pleopoda	present	absent

The present species is also close to *Cancricepon elegans* GIARD & BONNIER in its general appearance, but this species has four medio-dorsal processes, besides having endopodites on the pleopoda.

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THE INFLUENCE OF WAVE LENGTHS OF LIGHT ON THE BEHAVIOUR OF YOUNG MARINE FISH*

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INTRODUCTION

There have been various opinions on the question of whether or not fish have color sense. C. HESS (1912) did not consider that fish may have color sense. K. v. FRISCH (1912) and L. H. WARNER (1931) stand on the affirmative side from the experimental studies of fish behaviors. As a result of the histological investigation of fish eyes by R. KRAUSE (1923), however, it was made clear that cells of color sense exist in the retina of fish. Therefore, today color sense of fish is generally believed to exist. Because of the research of E. D. ADRIAN and R. MATTREWS (1927) on the light stimulation of fish eyes made through measuring action current of the optic nerve, a step was made in the progress of this field of study. However as his research was limited to the optic nerve of *Conger vulgaris* there still remains vast room for further study of other fish. The authors have done this research to determine the relationship between the color sensibility of fish eyes and the kind of light which is best for the attraction of fish by the use of lamps.

This research was carried out at the Ichthyological Research Institute, by means of a subsidy granted by the Fisheries Research Institute Fund. The authors wish to express their sincere thanks to the former President, Mr. KASUGA, and the present President, MURAYAMA of the Institute and they also express their deep gratitude to Dr. Y. OKADA, Professor of the Prefectural University of Mie, Dr. K. HUKUDA, Professor of Tôkyo University, and Dr. A. AZUMA of Mazda Institute for their kind suggestions.

MATERIAL USED

Six different species of young marine fish which were caught in the

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* Contribution from the Ichthyological Research Institute.

Table 1. Marine fish species used as materials

Name	Body length cm.
Oplegnathus fasciatus (T. & S.)	2— 5
Monacanthus cirrhifer T. & S.	2— 3
Cybium niphonium T. & S.	2— 4
Spheroides niphobles T. & S.	3— 7
Sphyraena japonica C. & V.	12—15
Anguilla japonica T. & S.	8— 9

sea near the laboratory were used as materials (Table 1).

The authors regret that adult fish could not be used in these experiments because of equipment limitations, but they are expecting to do further research on the adult fish of some important species.

These fish, after being caught in the sea, were kept in aquariums in the laboratory and were used according to the need.

EQUIPMENT FOR EXPERIMENTS

A lusterless, black, round wooden tank, which was 100 cm in diameter and 25 cm in height, was adopted for these experiments (Figure 1).

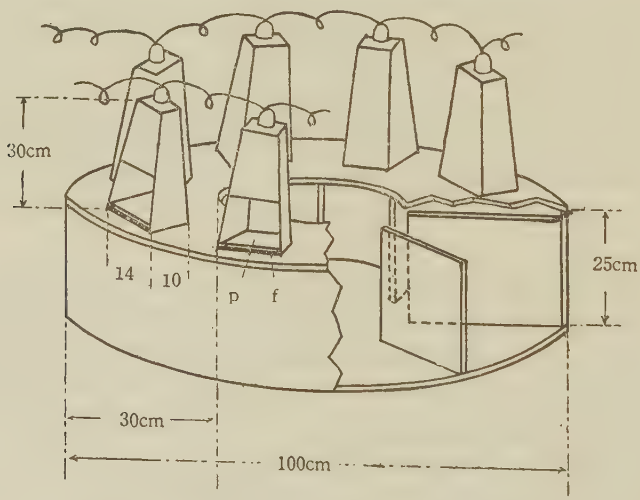


Fig. 1. Equipment for the experiments of the fish Gathering rate.

The tank was divided radially eight compartments, which were open to each other at the center, by eight 30 cm long boards. The tank was filled with sea water to a depth of 20 cm. A 10 cm×14 cm color filter was placed over a light window of each compartment and a 60 watt Mazda electric bulb

was set 20 cm above each filter. In order to make the illumnation for the colored lights equal to 50 lux on every water surface of the eight compartments some white papers were used for adjusting the light.

The color filters were arranged in two ways, one in order of wave lengths (Figure 2, a.) and the other at random (Figure 2, b.) so that the fish might not become familar with the color arrangement.

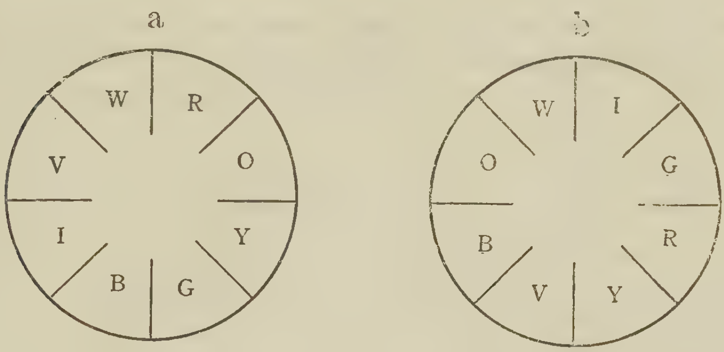


Fig. 2. The arrangements of color filters on the equipment.

The color filters which were used in the experiment were made by the Ôsawa method, that is, by dissolving 0.8 g of color element in a 6% gelatine solution and using 8 cc of it in painting a 12×16 cm glass pane. But green and blue filters were made in a different way as indicated in the following Table 2 and Note 2.

Table 2. Color elements of filters

Filters	Color elements
Red	Kongo rot.
Orange	Methyl orange, Tropaolin.
Yellow	Naphtol yellow.
Green	Methyl grün, Naphtol yellow.
Blue	Anilin blau, Thionin Ehrlich.
Indigo	Bleu de lyon, Methyl violet.
Violet	Methyl violet.

Note:

1. The filters for orange and indigo were devised by combining two filters which were made of two different color elements as shown in Table 2.
2. The filters for green and blue were made by mixing color elements as follows:

Green filter

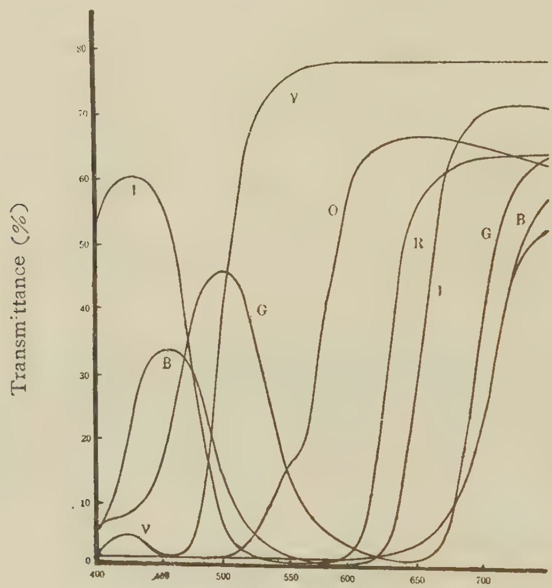
Naphtol yellow 0.8 g } 10 cc
94% alcohol 20 cc
6% Gelatine solution 20 cc } 10 cc } 8 cc spread on 12×16 cc glass pane.
Methyl grün 0.5 g } 5 cc
6% Gelatine solution 20 cc

Blue filter

Anilin blau 0.1 g
Thionin Ehrlich 0.05g } …8 cc spread on 12×16 cm glass pane.
6% Gelatine solution 20 cc

3. Frosted glass was used for white light.

The transparencies of the color filters made in the above mentioned ways were measured by the recording spectrophotometer as is shown in Figure 3.



Wave length in millimicrons

Fig. 3. Transmittance of light through color filters.

EXPERIMENT 1

Method.

This experiment was carried out in a dark room during the day-time by the preference method. The test fish, which were kept in an aquarium for about a week after being taken from the sea, were made accustomed to darkness in the experiment tank (Figure 1) for at least 30 minuites before the experiment. Then lighting the eight lamps at the same time, the authors recorded for ten minutes the number of fish which entered in each compart-

ment in every minute. At this time, those that went out of the compartment were not recorded and these present were counted as new comers every minute. During this experiment all test fish were very active and were not observed to stay long at any one place. The authors made five measurements each of the two arrangements (Figure 2, a and b) and figured out the fish gathering rate in percentages.

Result.

The average results of the measurements determined by the above mentioned method are shown as follows:

Table 3. Gathering rate (%) of *Oplegnathus faciatus* for various wave lengths of light. (Wat. temp. 25.8–27.4°C)

Exp.		a—arrangement					b—arrangement					average		
		1	2	3	4	5	1	2	3	4	5	a–m	b–m	M
Colors	R	0	0	0	0	0	0	0	0	0	0	0	0	0
	O	3.4	0	0	0	2.7	3.8	1.7	1.3	0	0	1.2	1.4	1.3
	Y	5.9	1.1	5.7	5.7	3.4	3.8	2.5	3.2	3.2	2.6	4.3	3.1	3.7
	G	30.2	48.9	40.2	40.8	40.3	40.0	42.3	38.2	43.9	41.8	40.0	41.3	40.6
	B	18.3	24.1	32.1	28.4	42.2	38.8	35.7	36.7	37.9	40.7	29.0	38.0	33.5
	I	11.5	3.0	9.6	10.4	1.6	5.8	8.4	8.4	7.2	6.7	7.2	7.3	7.3
	V	5.6	2.8	2.0	1.8	0	1.5	0	2.4	3.5	0	2.5	1.5	2.0
	W	25.6	20.1	14.9	14.6	9.5	6.4	9.1	8.5	5.0	5.0	16.4	6.8	11.6

Table 4. Gathering rate (%) of *Monacanthus cirrhifer* for various wave lengths of light. (Wat. temp. 24.8–25.0°C)

Exp.		a—arrangement					b—arrangement					average		
		1	2	3	4	5	1	2	3	4	5	a–m	b–m	M
Colors	R	7.5	4.5	10.5	12.0	7.5	1.0	3.0	3.0	2.0	2.0	8.4	2.2	5.3
	O	4.0	2.0	2.0	10.0	4.0	1.0	5.0	6.0	2.0	6.0	4.4	4.0	4.2
	Y	7.5	11.0	8.5	7.5	5.5	3.0	11.0	3.0	6.5	8.0	8.0	6.3	7.2
	G	37.5	29.0	27.5	32.0	33.0	36.5	19.0	28.0	35.0	25.0	31.7	28.7	30.2
	B	22.0	24.5	30.0	29.0	33.0	36.5	31.0	31.0	33 0	29.0	27.7	32.1	29.9
	I	5.5	15.5	19.0	2.0	7.5	5.0	22.0	21.0	17.0	8.0	9.9	14.6	12.3
	V	0	0	0	0	0	0	0	0	0	0	0	0	0
	W	17.0	13.0	2.0	7.5	9.0	16.0	9.0	6.0	4.0	22.0	9.7	11.4	10.6

Table 5. Gathering rate (%) of *Cybium niphonium* for various wave lengths of light. (Wat. temp. 19.0–19.2°C)

Exp.		a—arrangement					b—arrangement					average		
		1	2	3	4	5	1	2	3	4	5	a–m	b–m	M
Colors	R	1.6	0	0	0	0	0	0	9.0	0	1.5	0.3	2.1	1.2
	O	7.3	7.7	1.5	6.7	0	12.2	0	13.4	0	13.8	4.7	7.9	6.3
	Y	14.6	7.7	18.5	3.3	13.7	0	0	4.5	2.8	3.1	11.6	2.1	6.8
	G	26.1	26.2	29.2	24.4	63.7	12.2	33.0	50.7	27.8	27.7	32.8	28.3	30.5
	B	50.0	32.3	29.2	35.6	20.5	64.5	71.0	11.0	69.5	50.7	33.5	53.5	43.5
	I	3.1	10.8	18.5	14.4	1.4	3.3	6.3	10.5	0	0	9.6	4,0	6.8
	V	0	1.5	3.1	12.2	1.4	0	0	0	0	1.5	3.6	0.3	2.0
	W	0	13.9	0	3.3	0	7.8	0	0	0	1.5	3.4	1.9	2.7

Table 6. Gathering rate (%) of *Sphyraena japonica* for various wave lengths of light. (Wat. temp. 19.0–19.2°C)

Exp.		a–arrangement					b–arrangement					average		
		1	2	3	4	5	1	2	3	4	5	a–m	b–m	M
Colors	R	1.2	0	1.3	4.9	2.5	0	0	7.5	10.7	0	2.0	3.6	2.8
	O	17.9	8.2	9.0	4.9	16.3	12.5	11.7	3.7	8.3	12.0	11.3	9.6	10.5
	Y	14.3	18.0	24.4	11.1	10.0	2.1	11.7	8.4	5.9	13.3	15.6	8.3	12.0
	G	17.9	24.6	14.1	26.0	22.5	31.3	26.7	30.0	36.9	30.6	21.0	31.1	26.1
	B	36.9	39.4	18.1	23.4	15.0	37.5	35.0	30.0	35.8	33.4	26.5	34.3	30.4
	I	4.8	8.2	11.5	7.4	10.0	6.3	6.7	8.4	0	5.3	8.4	5.3	6.8
	V	0	0	10.3	7.4	10.0	2.1	5.0	3.7	2.4	2.7	5.5	3.2	4.4
	W	7.1	1.6	11.5	14.8	13.7	8.3	3.3	8.4	0	2.7	9.7	4.5	7.1

Table 7. Gathering rate (%) of *Spheroides niphobles* for various wave lengths of light. (Wat. temp. 18.8–19.2%°C)

Exp.		a–arrangement					b–arrangement					average		
		1	2	3	4	5	1	2	3	4	5	a–m	b–m	M
Colors	R	0	0	8	0	0	0	2	4	2	0	1.6	1.6	1.6
	O	2	12	8	8	6	9	3	2	6	0	7.2	4	5.6
	Y	2	20	18	22	6	27	38	35	24	40	13.6	32.8	23.2
	G	20	18	18	10	26	17	25	31	26	44	18.4	28.6	23.5
	B	28	26	16	26	16	27	25	16	20	6	22.4	18.8	20.6
	I	16	2	8	0	16	0	1	1	0	0	8.4	0.4	4.4
	V	14	10	4	2	2	0	0	0	0	0	6.4	0	3.2
	W	18	12	20	32	28	21	6	11	22	16	22.0	14.0	18.0

Table 8. Gathering rate (%) of *Anguilla japonica* for various wave lengths of light. (Wat. temp. 23.7–25.0°C)

Exp.		a—arrangement					b—arrangement					average		
		1	2	3	4	5	1	2	3	4	5	a-m	b-m	M
Colors	R	18.8	17.4	15.8	15.2	18.2	23.0	17.1	15.4	7.4	21.3	17.1	18.8	18.0
	O	15.3	18.5	14.3	16.5	13.1	15.7	24.2	22.0	12.7	10.2	15.5	17.0	16.3
	Y	9.0	8.7	6.6	9.0	10.1	6.5	4.3	5.8	6.4	7.4	8.7	6.1	7.4
	G	15.3	13.0	16.9	11.7	10.1	10.3	10.0	13.5	10.1	12.0	13.4	11.0	12.2
	B	9.0	7.6	10.9	15.8	11.1	9.3	10.0	13.5	11.0	6.5	10.9	10.0	10.5
	I	12.6	13.0	10.9	6.9	11.1	15.7	14.3	8.7	17.4	16.7	10.9	14.6	12.8
	V	9.0	17.4	13.1	15.2	20.2	13.9	24.2	15.4	27.2	21.3	15.0	20.4	17.7
	W	10.8	4.3	11.5	9.7	6.1	5.5	8.6	6.4	6.4	4.6	10.7	6.4	8.5

In these six tables, "a-m" and "b-m" indicate the mean fish gathering rates of Figures 2, a and Figure 2, b arrangements respectively, and "M" shows the mean value of the above mentioned rates. These are illustrated by Figures 4 and 5. In these two figures, lines "w-a" and "w-b" show the fish gather ing rates for white light as shown in the Figure 2, a and Figure 2, b arrangements respectively. The mean value of these rates is indicated by "w-M".

In figures 4 and 5, it is worth noticing that "a-m" and "b-m" come close to each other. It was further learned that five species all, except *Anguilla*, have a tendency to remain mostly in the green and blue compartments. The authors named this group of fish "A" and the other "B". Even among "A" group fish, there are two kinds, one of them showing definite light-seeking tendency for each wave length of light as compared to white light, and the other group such as *Spheroides*, showing the colored light-seeking tendency to a lesser degree.

In order to determine whether it was because of the wave length or the energy of each color that so many fish showed preference for the green and the blue lights, the following experiment was carried out.

EXPERIMENT 2

Method.

The same test species (except *Anguilla*) and equipment as that for the first experiment were used in this one. But this time the authors adopted the blue and the red light only, the colors which attracted the most and the least fish respectively in the previous experiment and the two bulbs were placed above the two opposite compartments. In this experiment the blue

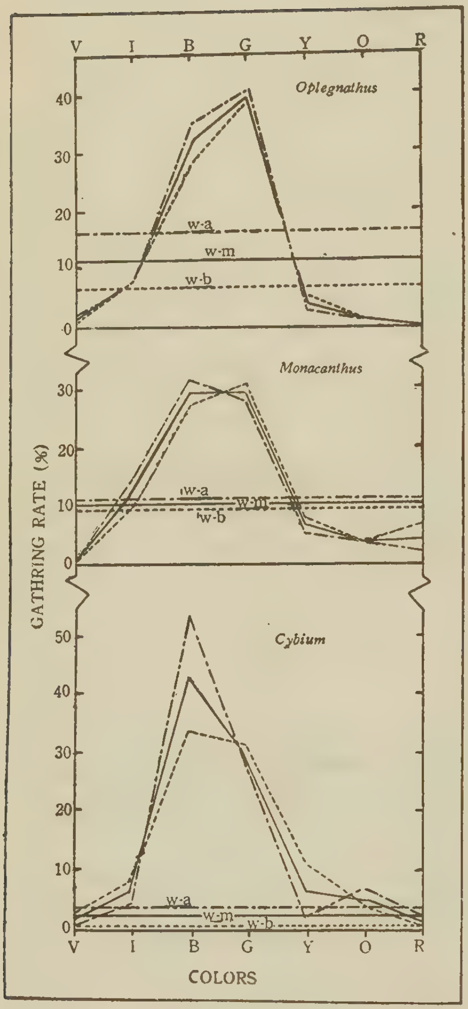


Fig. 4. The relation between the fish gathering rates and colors.

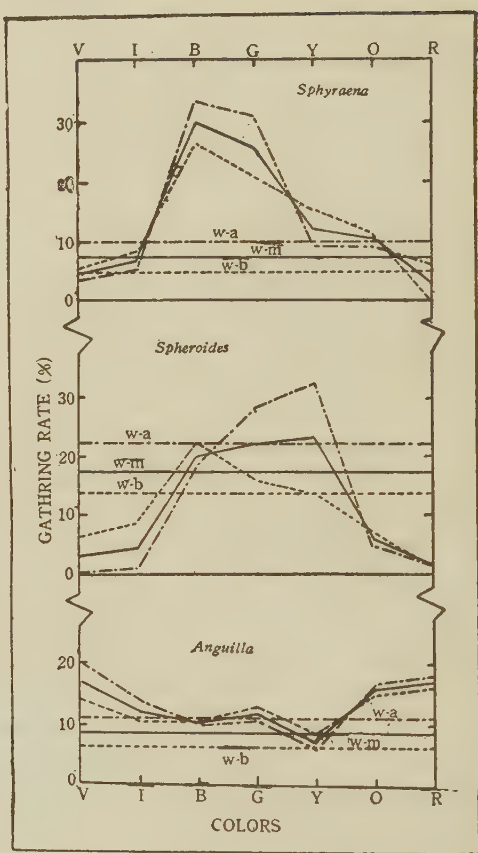


Fig. 5 The relation between the fish gathering rates and colors.

light is designated by "L" and the red light by "l".

The experiment was begun with 50 lux illumination on the water surface of both compartments. After making the test fish accustomed under the two colored lights for 30 minutes, the authors gradually decreased illumination of "l" until at last it become 0 lux, by piling up the screening papers on it while keeping the illumination of "L" the same. Then the authors shifted the screening papers from the "l" filter to the "L" filter one by one and thus made the illumination of "l" larger and of "L" smaller, until the

illumination of "1" and "L" reached 50 and 0 lux respectively. During this process the fish had at first gathered in the "L" compartment at a certain light intensity. With the same process of operation, but in the opposite condition of light making "1" and "L" 50 and 0 lux respectively, the experiment was continued. In this condition, of course, the fish moved from the "1" compartment into the "L" compartment, at a certain point. Thus, the fact became known that there are certain limits at which fish removed from one light wave length region to the other.

Results.

Measuring the illumination on the water surfaces of both the "1" and "L" compartments at the time when the fish began to move from one compartment to the other, the authors obtained the results shown in Table 9.

Table 9. The relation between the luminosity of L and that of 1 at the time the fish reverse their preference

Fish	Exp. A		Exp. B	
	L lux	1 lux	L lux	1 lux
Oplegnathus	15	50	3	12
Monacanthus	17	,,	0–3	12–15
Cybium	12—15	,,	3–8	8–12
Sphyraena	15	,,	3	12
Spheroides	24	,,	3	12

The changing of the fish-gathering reaction from one light to the other was observed when the ratio of the illumination of "L" and "1" was between 1–3 and 1–4. The results of the careful experiment with *Sphyraena* in line with this study is shown in the Table 10.

Table 10. The relation between illuminations of blue and red at the time *Sphyraena* reversed its preference

L (Blue)	1 (Red)
15 lux	50 lux
,,	24
12	17
10	15
3	12
3	8

As it seems too hasty to conclude only from the above mentioned experiments that the reaction of fish to light is influenced only by the difference of wave-length, the study on the energy of light will be considered in the following section.

CONSIDERATION

As stated in the third section of this report. "Equipment for experiments", a 60 Watt Mazda bulb was used for the light source and the illumination was measured by a ceren photo-cell.

First of all, in terms of the transparency shown in the Figure 3, the transparency "T" of every colored filter for the spectoral radiant intensity "E" of the bulb was calculated, and also the energy of the light of this bulb for every colored filter was figured by the expression, $\int E_\lambda \ T_\lambda \ d\lambda \cdots\cdots B$ (cf. Figure 6). Moreover, the sensibility "S" of the ceren photo-cell for the transparency "T" of each color filters was calculated by the spectol sensibility curve of a ceren photo-cell. The energy for the sensibility was also figured by the expression, $\int E_\lambda \ T_\lambda \ S_\lambda \ d\lambda \cdots\cdots A$ (of. Figure 7).

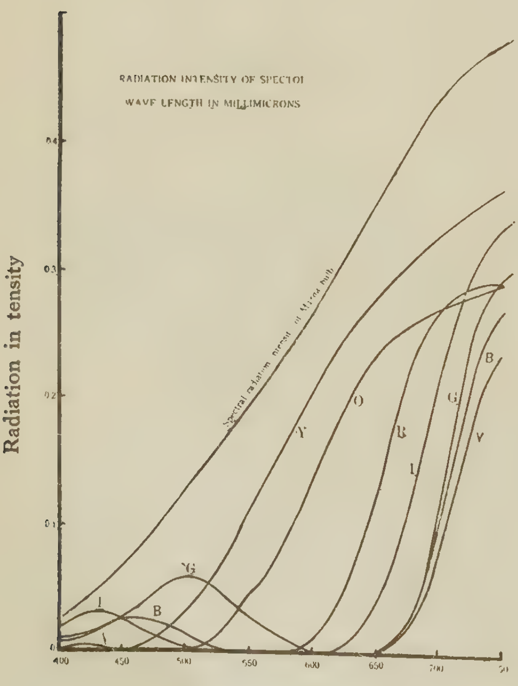


Fig. 6. Spectral sensibilities of the ceren photocell through color filters.

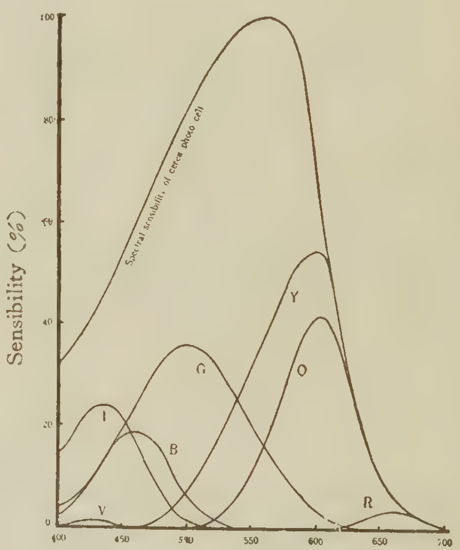


Fig. 7. Spectral radiation intensities of light of 60 W Mazda bulb through color filter.

The figures thus obtained were substituted into the expression, Bx / A (x here means the figure on the ceren luxmeter), and the relative energy for each colored light was obtained. Table 11 shows the results of the above mentioned calculations.

Table 11. Relative energies of colors used

Colors	B	A	Bx/A
Violet	222	3	3,700
Indigo	543	155	175
Blue	356	136	130
Green	458	391	128
Yellow	1,405	502	140
Orange	1,014	310	162
Red	698	6	5,800

(calculated as x=50 the figure of the ceren luxmeter)

Table 12. The values of Table 9 converted to relative energies

Fish	Exp. A		Exp. B	
	L. Bx/A	1…Bx/A	L. Bx/A	1…xB/A
Oplegnathus	39.2	5,800	7.9	1,3900
Monacanthus	44.5	〃	0– 7.9	1,300–1,740
Cybium	31.4–39,2	〃	7.9–21.0	930–1,390
Sphyraena	39.2	〃	7.9	1,390
Spheroides	62.8	〃	7.9	1,390

According to this table, red and violet have the largest relative energy and blue and green have the smallest. Judging from this fact, it was thought that the greatest values of the fish-gathering rate of the A group fish was due to the low energy light as well as the blue and green wave lengths. The

Table 13. The values of Table 10 converted to relative energies

Blue	Red
39	5,800
30	2,784
31.2	1,972
26	1,740
7.8	1,392
7.8	923

values of Table 9 and 10 were converted to show the relative light energies (Table 12 and Table 13) and the values in Table 13 results are shown in the following Figure.

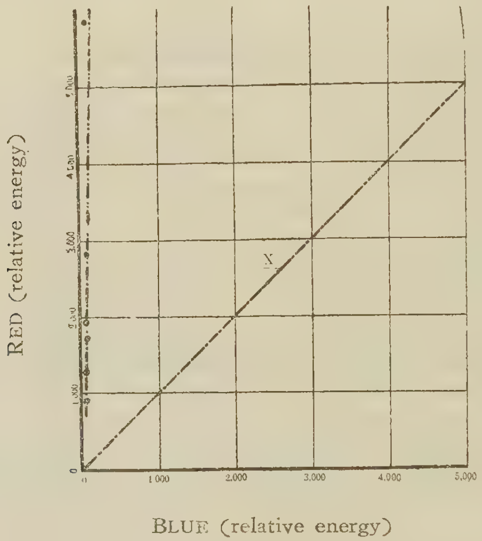


Fig. 8. Showing the relation between the relative energies of blue and red at the inversion point of the phototaxis of fish.

In this figure, if the fish gathering rate of the A group fish changed according to the amount of the energy, the relationship between blue and red should be expressed on the diagonal line (X). However, the line (Y) which indicated this relationship declines greatly to red. In other words, it shows that the region for which *Sphyracna* showed preference was relatively richer in blue than in red. Judging from this fact, the fish gathering rate was found to be due largely to the wave length of blue rather than its energy.

Following the same reasoning, it is concluded that the preference of the group "A" fish for the blue is due primarily to the wave length, if Table 12 is taken into consideration. The same thing can be said concerning the fish-gathering rate for green.

According to the first experiment (see Figures 4-5), *Cybium, Oplegnathus, Monacanthus* and *Sphyraena* show greater gathering rates for blue and green light than for white light. But *Spheroides* show smaller gathering rate for green and blue as campared to white light than those species mentioned above. Besides, some fish such as *Oplegnathus* and *Spheroides,* were observed to show a quite different gatheringrate for the white lamp because of light

arrangements ("a" arrangement and "b" arrangement in Figure 2), while others did not.

SUMMARY

1. According to the results of this experiment, among the eight lights, green and blue produce the greatest fish-gathering rates. It was found that there are two fish-groups, A and B, and their reactions to light are quite different. *Oplegnathus, Monacanthus, Cybium, Spheroides* and *Sphyraena* belong to the former and only *Anguilla* belongs to the latter.

2. From this experimet, it can be considered that the light-seeking tendency of group "A" fish is due not to the energy of the light; but rather to the wave-length of the light.

3. Even group "A" fish can be classified into two different sub-group one has almost no white light-seeking tendency e. g. *Cybium* and *Sphyraena*, and the others has a fairly strong white-light seeking tendency, e. g. *Spheroides*.

4. Considering the fish-gathering rate for white light as a standard, *Anguilla*, which belongs to B group, shows almost no reaction to blue, green, indigo and yellow; but shows a distinct light seeking tendency for violet and red.

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ON THE RELATION BETWEEN THE PHOTOTAXIS AND THE AGGREGATION OF YOUNG MARINE FISHES*

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INTRODUCTION

In a biological phenomenon, the aggregation frequently comes into question. It is commonly known that when more than two individuals gather, they form a society and the state of "gathering" brings forth a new phenomenon.

Some researches have already been made on the formation of aggregation of fish. For instance, EDDY (1925), BOWEN (1931) and SATÔ (1937) stated that fish form aggregations by means of their optical sense. These researches, however, have probably been made on the assumption that apparent gatherings are real aggregations. Nevertheless, it is possible that two fish actually form an aggregation even when they are so apart from each other that they cannot be considered as a group. Therefore, it is next to impossible to conclude from the appearence whether a gathering is an aggregation or not

In our study on the Phototaxis of fish, it is necessary to conduct researches on how aggregation affects the phenomenon and what difference exists between the phototaxis of the individual fish and that of the aggregated fish. The writer intends to report on the result of the experiment which he made concerning these matters.

This research was studied at the Ichthyological Research Institute. The author wishes to thank Dr. N. Y. KAWAMOTO, Head of the Institute, for his kind suggestions extended towards this research.

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* Contribution from the Ichthyological Research Institute.

MATERIALS EMPLOYED FOR EXPERIMENT

Though *Plotosus angullaris* L. is famous for its distinguished tendency to aggregation, it could not be used in this experiment because of its too strong tendency to group. As the fish which shows stronger phototaxis was more adequate, the author employed young *Girella punctata* G. and *Mugil cephalus* (L.) which were captured near the institute. These fishes were provided for the experiment after having been bred in a tank for a certain days. The average body lengths of *Girella* and *Mugil* were 3.0—4.5cm and 2.5—3.5cm respectively.

METHOD OF EXPERIMENT

Along the edge of a round water-tank, the writer made eight fan-shaped compartments, each of which was opent to the center. On each compartment, a Riken-made monochromatic filter was set so that each colored light poured into the responding compartment. The central wave lengths of the filters were 430, 470, 500, 530, 570, 610, 660, 720 mμ. The widths of the filtering lights were approximately 50 mμ. As the source of light an A.C. 60W bulb was employed.

First the fish were placed in the above-mentioned tank, while the laboratory was dimly lit. After 30 minutes had passed, the bulbs were turned on and the measuring was promptly begun. As for the method of measuring, the author recorded every 15 seconds which compartment the fish stayed in, and this recording was continued for 16 minutes. In order to avoid the effect of the schooling of fish made by the repeated experiment, the different fishes were used for each experiment. For one-fish experiment, the measurement was taken on 50 fishes. For two-fish and three-fish experiments, researches were done 20 times. And in the case of ten-fish experiment, the result was gained from 10 measurements.

With regard to the method of calculation, the mean of the figures gained through four measurements of T minute 0 second, T min. 15 sec., T min. 30 sec. and T min. 45 sec. was considered as the mean value of T minute. In this case, however, the value of 0 min. 0 sec. was excepted. The mean value at each compartment which was calculated in the above mentioned way, was converted into percentage for every minute. Besides the mean value M, the author calculated the standard deviation and the variant coefficient V for 16 values from 0 m. to 15 m.

At the experiment on the type of aggregation, the author also made measurements every 15 seconds. In this case, it was needless to measure on each filter. The auther only investigated the types of the aggregation which the experimental fish formed. In the same method of calculating, as made in

the previous experiment the mean value was found out, and the variation by time was examined. Concerning the relationship between the aggregation and the curve of fish-gathering rate by wave-lengths, the author recorded the types of aggregations while counting the number of fish gathered under filters, and calculated the result according to the type of aggregation.

RESULTS OF EXPERIMENT

(I) On *Girella punctata* G.

In the above mentioned method, the experiments were first carried on one *Girella punctata* and then on ten. The curves of fish gathering rate in relation to the wave lengths, which were drawn from the result of these experiments are shown in Table 1, Fig. 1 and Fig. 2.

Tab. 1. On the gathering rates of *Girella punctata* in relation to the wave length of light.

Filters	One-fish experiment			Ten-fish experiment		
	M	σ	V	M	σ	V
430	12.5	2.8	0.22	12.8	4.2	0.33
470	15.8	2.1	0.13	24.3	5.8	0.24
500	9.5	2.7	0.27	28.0	6.3	0.23
530	14.1	2.8	0.20	14.4	5.1	0.35
570	13.5	3.5	0.26	12.4	4.3	0.35
610	13.9	2.2	0.16	3.8	2.1	0.55
660	10.1	2.4	0.24	3.2	1.8	0.56
720	10.6	1.9	0.18	4.1	2.2	0.54

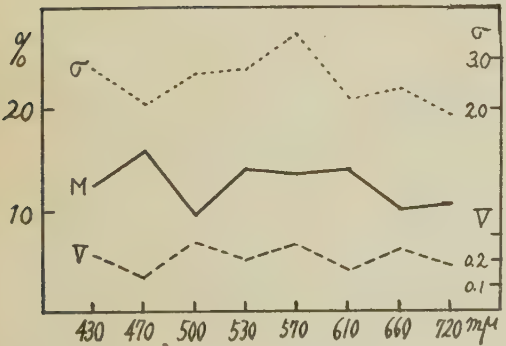


Fig. 1. Curve of gathering rate in relation to the wave length of light in one-fish experiment. M: mean; σ: standard deviation; v: Variant coefficient. (*Girella punctata*)

By these curves you will know that at one-fish experiment the fish gathering rates of different filters are almost nearby the same while at ten-fish experiment, that of the filter of 500 mμ shows the highest. This difference is very remarkable. The curve of the latter experiment presents the same type of the curve which is seen in the paper of KAWAMOTO and TAKEDA (1950). However, at the former experiment, there seems to be no wave length which particularly attracts fish.

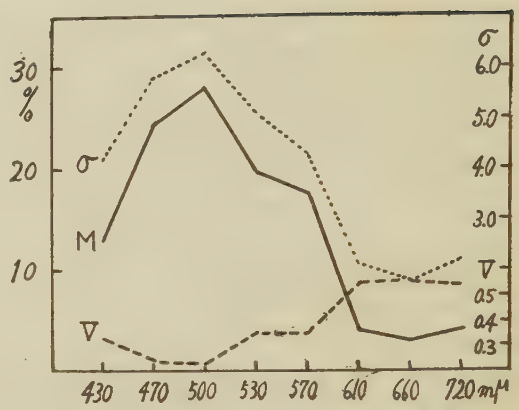


Fig. 2. Ten-fish experiment. (*Girella punctata*)

Here, the author considers it necessary to mention the individual records of each fish. If we examine the curve of fish-gathering rate of each fish, we will notice that the wave lengths which indicate the maximum rate are various according to the fish experimented. This is entirely against the presumption, which might be gained through the results of the ten-fish experiment, that the wave-lenghts of blue and green will attract more fish. This is the reason why the curve in the Fig. 1 is comparatively even. Such is the case of one-fish experiment. At the ten-fish experiment, however, the curve shows rising at the blue and green. This must be, it is supposed, due to the aggregation.

The standard deviation which runs alongside the mean, M shows the variation of sixteen mean values. In Fig. 1 σ runs irregularly, while in Fig. 2 this does parallel with M. It is commonly accepted that in most phenomena, the larger the mean value is, the larger the standard deviation becomes. Therefore, the variant coefficient V which is the ratio of σ to M is often used to discuss the variation of the mean. In this case, the reversed tendency of σ is seen. In the ten-fish experiment, the greater M shows the less V. In other words, it is safely regarded that the higher fish gathering rate a wave length holds, the more constant number of fish it attract.

Tab. 2. On the gathering rates of *Mugil cephalus* in relation to the wave length of light.

	1 fish exp.			2 fish exp.			3 fish exp.			10 fish exp.		
Filters	M	σ	V	M	σ	V	M	σ	V	M	σ	V
430	13.9	2.5	0.18	12.4	4.7	0.38	13.1	6.3	0.48	12.8	5.3	0.41
470	14.2	3.5	0.25	16.8	6.1	0.36	15.7	5.2	0.33	16.3	6.4	0.39
500	15.0	4.2	0.28	26.0	5.8	0.22	22.5	7.2	0.32	22.4	7.3	0.33
530	13.7	3.4	0.25	20.0	6.1	0.31	16.3	7.0	0.43	17.5	7.1	0.41
570	10.7	4.4	0.41	8.5	3.9	0.46	11.6	4.6	0.40	13.2	6.2	0.47
610	15.5	2.8	0.18	6.9	5.1	0.74	10.6	3.9	0.37	7.8	4.8	0.61
660	7.3	2.9	0.40	4.1	3.1	0.76	6.6	3.3	0.50	5.2	3.5	0.67
720	10.2	3.1	0.30	4.7	3.4	0.72	3.3	2.1	0.64	4.5	2.9	0.65

(II) On *Mugil cephalus* (L.)

In order to confirm the result of the experiment made by *Girella punctata,* same kind of tests were proceeded using *Mugil cephalus.* This time the numbers of fish employed at each experiment were one, two, three and ten. The results of these experiments are shown in Table 2 and Fig. 3～6.

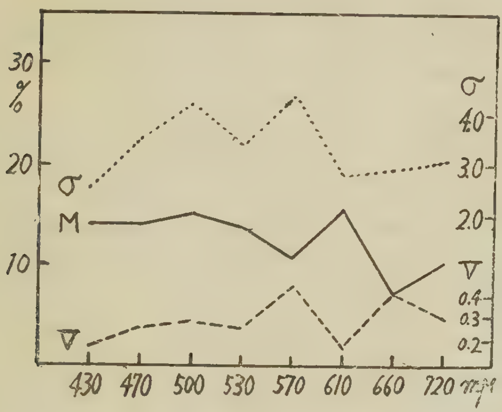


Fig. 3. On the relation between gathering rate and wave-length of light in one-fish experiment. (*Mugil cephalus*)

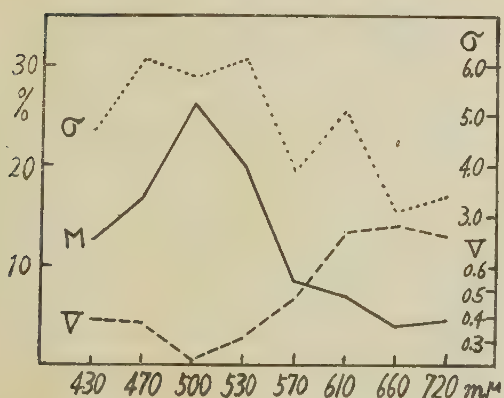


Fig. 4. Two-fish experiment. (*Mugil cephalus*)

In this case, like the result of the previous experiment, one-fish experiment produced a different result from that of the aggregations. The fish-gathering curve of one fish test is a almost horizontal while curves for two, three and ten fish are convex in shape.

The standard deviation is parallel with the means. The larger variant coefficient, on the contrary, corresponds with the smaller means. Furthermore, at one-fish experiment of *Mugil cephalus,* like *Girella punctata,* they do not gather to a particular wave length. In the experiment, they gradually lost their preference to the light as time went on, and in the end they remained at the dark center. This tendency of *Mugil cephalus* is remarkably different from that of *Girella punctata* G. which tend to gather under the light.

Judging from the result of the experiment on *Girella punctata* and *Mugil cephalus,* it is found that the convex curves of the fish gathering rate which we have gained, are the result of collected data obtained through the experiments of aggregation of fish. But if we calculate the results of one fish tests made on many fish, the rinsings of the curves will not probably come out. Accordingly, the problem seems to lie in the difference between one fish and

two fish. Of course, there might be some difference between two fish and three fish, between three fish and four fish and so on. However, these differences will not show themselves on the curve of the fish gathering rate distinctively.

In order to examine this result, the author carried out the following experiments.

(III) On the rate of the frequency of appearance of each type of aggregation.

It is very difficult to judge whether two fish in a tank are behaving as one aggregation or two individuals. As the author mentioned before, two fish are possibly influencing each other, even when they are swiming far apart. However, it is possible to judge that two fish are forming aggregation or not by means of establishing a certain rule. For instance, we consider it an aggregation when two fish are in the same room or swin in a row. Standing on such a supposition, the author investigated on the rate of the frequency of appearance of each type of aggregation (RFA). The experiment was proceeded for 16 minutes during which the state of aggregation was recorded every 15 seconds. Through calculating these records every minutes the variation by time was persuaded.

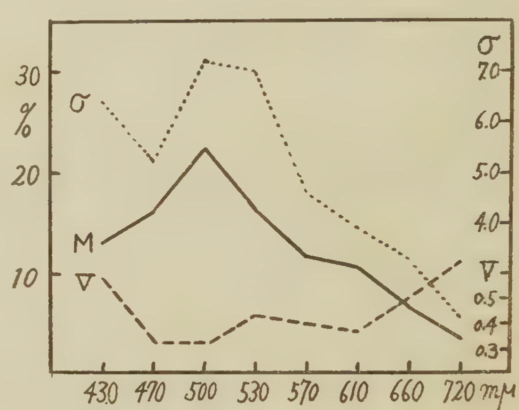


Fig. 5. Three-fish experiment. (*Mugil cephalus*)

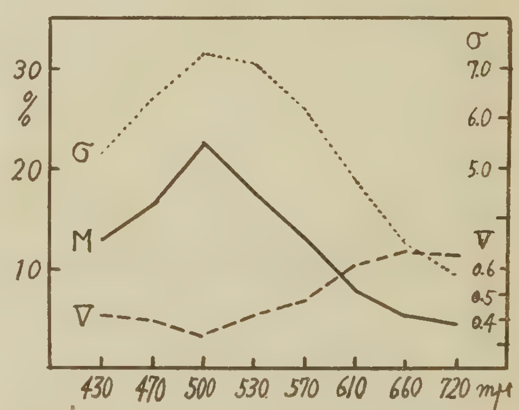


Fig. 6. Ten-fish experiment. (*Mugil cephalus*)

1. In case of Two Fish.

In this case the conditions of the fish are two; whether they are behaving independently or forming an aggregation. For the sake of convenience, the former was marked $G_{(1,1)}$ and the latter $G_{(2)}$.

Tab. 3. RFA of two-fish experiment

	min.	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	mean
I	G (1.1)	0.37	0.25	0.34	0.32	0.28	0.15	0.21	0.22	0.10	0.25	0.26	0.40	0.36	0.28	0.31	0.35	0.28
	G (2)	0.63	0.75	0.66	0.68	0.72	0.85	0.79	0.78	0.90	0.75	0.74	0.60	0.64	0.72	0.69	0.65	0.72
II	G (1.1)	0.36	0.45	0.52	0.47	0.61	0.65	0.33	0.51	0.30	0.41	0.24	0.10	0.15	0.16	0.21	0.13	0.35
	G (2)	0.64	0.55	0.48	0.53	0.39	0.35	0.67	0.49	0.70	0.59	0.76	0.90	0.85	0.84	0.79	0.87	0.65
III	G (1.1)	0.02	0.10	0.05	0.03	0.04	0.21	0.18	0.20	0.11	0.15	0.28	0.31	0.44	0.36	0.55	0.38	0.21
	G (2)	0.98	0.90	0.95	0.97	0.96	0.79	0.82	0.80	0.89	0.85	0.72	0.69	0.56	0.64	0.45	0.62	0.79
IV	G (1.1)	0.33	0.50	0.35	0.41	0.20	0.36	0.77	0.65	0.38	0.40	0.45	0.67	0.43	0.82	0.52	0.84	0.50
	G (2)	0.67	0.50	0.65	0.59	0.80	0.64	0.23	0.35	0.62	0.60	0.55	0.33	0.57	0.18	0.48	0.16	0.50

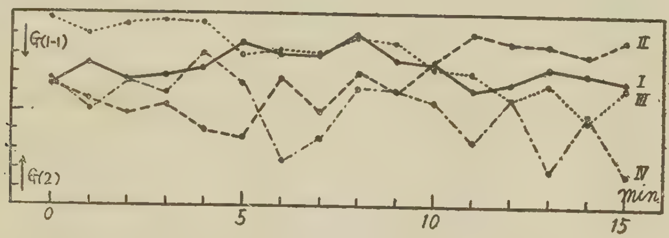


Fig. 7. Four courses of RFA of two-fish experiment.
$G_{(1.1)} + G_{(2)} = 1$

The relative frequency of these two factors is shown on Table 3 and Fig. 7. In the figure, the width of the vertical axis was made one so that they are fitted in the expression,

$$G_{(1.1)} + G_{(2)} = 1$$

Four curves in the figure, indicate four different results.

The curve I is a typical one at which $G_{(2)}$ is always dominant over $G_{(1.1)}$. It also shows comparatively stable tendency in the course of fifteen minutes. The Curve II shows that $G_{(1.1)}$ decreased while $G_{(2)}$ increase at the time went. The Curve III indicates the case that $G_{(1.1)}$ increased remarkably. The Curve IV shows the lack of stability and the large variation.

As it is clear in the above mentioned figures, the curve of RFA with relation to the time take the various course according to the combination of the fish. Roughly speaking, however, $G_{(2)}$ is larger than $G_{(1.1)}$. In other words, the fish prefers aggregation to being individual.

2. In Case of Three Fish

In this case, there are three states of fish, one is that each fish is separated, another is that two fish make an aggregation and the third is that

three fish are aggregated. These three cases are marked $G_{(1.1.1)}$, $G_{(1.2)}$, and $G_{(3)}$, respectively. And these cases are expressed, in Fig. 8, in such a way that satisfies the following expression.

Tab. 4. RFA of three-fish experiment

min.	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	mean
$G_{(1.1)}$	0.11	0.13	0.05	0.08	0.07	0.07	0.09	0.12	0.08	0.08	0.05	0.06	0.07	0.09	0.05	0.08	0.09
$G_{(1.2)}$	0.43	0.35	0.37	0.42	0.51	0.36	0.39	0.24	0.63	0.52	0.34	0.37	0.38	0.38	0.42	0.43	0.41
$G_{(3)}$	0.56	0.52	0.58	0.50	0.42	0.57	0.52	0.64	0.29	0.40	0.61	0.57	0.55	0.53	0.53	0.49	0.50

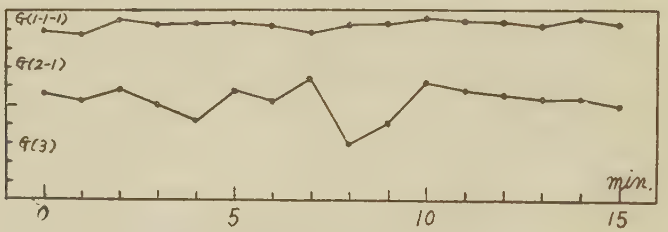


Fig. 8. RFA of three-fish experiment.
$G_{(1.1.1)} + G_{(1.2)} + G_{(3)} = 1$

$$G_{(1.1.1)} + G_{(1.2.)} + G_{(3)} = 1.$$

Fig. 8 and Table 4 show the result of the investigation made on *Mugil cephalus* (L.)

As it is clear in the figure, $G_{(1.1.1)}$ is very small in number. Besides, $G_{(1.2)}$ and $G_{(3)}$ look same each other with the former being a little smaller. This is probably because the changes from $G_{(1.2)}$ to $G_{(3)}$ and the vice verse frequently happen. It is interesting to notice that $G_{(1.1.1)}$ is very few. This is perhaps due to the fact that the tendency to form two-fish aggregation is intense, just as $G_{(2)}$ is larger than $G_{(1.1)}$ at the previous survey.

Same result would be expected at the experiment of more than four fish. But the accurate value could not be gained because of the difficulty in measurement. The author expects another chance to make investigation on more than four fish with the proper facilities.

(IV) RFA and the curve of the Fish Gathering Rate against the Wave Length.

As stated above, the fishes were constantly changing the form of a aggregation. Here the question was raised on the relationship between the type

of aggregation and the curve of the fish-gathering rate of the wave lengths.

While conducting the experiment of two and three fish in the method as stated in the previous sections, the author recorded the nature of aggregation which the fish made on the occasion of the measurements and at the end calculated them according to the sorts of aggregation.

Through the two-fish experiment were gained two curves of fish gathering rate for wave lengths which correspond to $G_{(1.1)}$ and $G_{(2)}$. These two curves were named as $C_{(1.1)}$ and $C_{(2)}$ respectively. The three curves which were obtained by the three-fish experiment were named $C_{(1.1.1)}$, $C_{(1.2)}$, $C_{(3)}$ corresponding to $G_{(1.1.1)}$, $G_{(1.2)}$ and $G_{(3)}$, respectively. The results are shown in Table 5, Fig. 9 and Fig. 10.

Tab. 5. Gathering rates in relation to the type of aggregation and the wave length of light.

Filters	2 fish experiment			3 fish experiment			
	$C_{(1.1)}$	$C_{(2)}$	g_2	$C_{(1.1.1)}$	$C_{(1.2)}$	$C_{(3)}$	g_3
430	13.2	8.4	9.3	14.8	10.2	12.1	11.7
470	12.0	13.5	13.2	11.5	13.4	16.6	14.9
500	14.4	24.3	22.3	12.2	20.2	28.7	23.7
530	15.2	21.4	20.1	13.9	17.5	18.3	17.8
570	11.8	11.3	11.4	12.4	12.3	9.8	11.0
610	13.2	9.6	10.3	10.3	10.3	6.2	8.2
660	11.2	7.2	8.0	12.2	10.1	4.6	7.5
720	9.0	4.3	5.2	12.7	6.0	3.7	5.5

Among these curves, both $C_{(1.1)}$ and $C_{(1.1.1)}$ are nearly horizontal bearing the resemblance to the results of one-fish experiment. $C_{(2)}$ has a rising. $C_{(1.2)}$ also shows a rising which lies between that of $C_{(3)}$ and $C_{(1.1.1)}$. In this experiment the relationship is expressed as follows.

$$G_{(1.1)} : G_{(2)} \fallingdotseq 0.2 : 0.8$$

Therefore, if the curve of fish gathering rate of two fish is named g_2, the following relationship ought to exist.

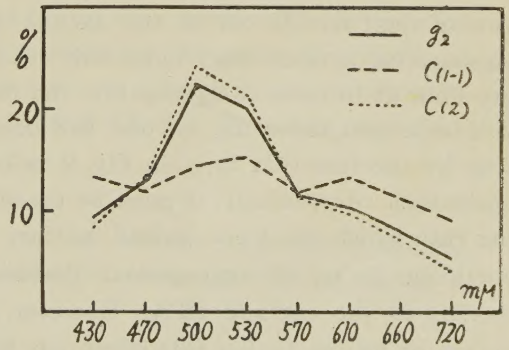


Fig. 9. The gathering rate in relation to the wave length of light in two-fish experiment.

$$g_2 = 0.2C_{(1.1)} + 0.8C_{(2)}$$

This is identified as the curve of two-fish experiment (It is shown by the full line in Fig. 9.) This curve correspond to the one in Fig. 4.

Supposing that $G_{(1.1.1)} : G_{(1.2)} : G_{(3)}$ equals 0.1 : 0.4 : 0.5 and that the curve of fish gathering rate by three fish is named g_3, the following expression is establishing.

$$g_3 = 0.1\,C_{(1.1.1)} + 0.4C_{(1.2)} + 0.5\,C_{(3)}$$

This expression corresponds to the curve in Fig. 5. Curve g_3 is denoted by the full line in Fig. 10.

As you see in the figures, there is not a clear distinction between $C_{(2)}$ and g_2 and between $C_{(1.2)}$, $C_{(3)}$, and g_3. The raison is that RFA of $C_{(2)}$, $C_{(1.2)}$, and $C_{(3)}$ are large enough to control g_2 and g_3.

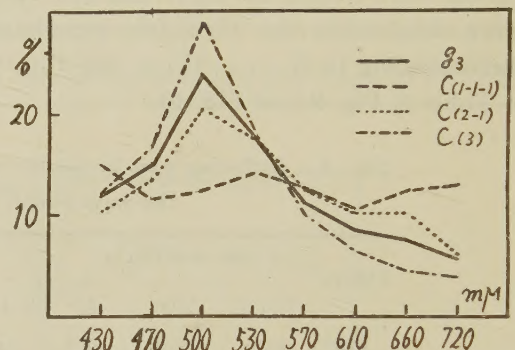


Fig. 10. The gathering rate in relation to the wave length of light in three-fish experiment.

CONSIDERATION

It is now clear, through the experiments of *Girella punctata* G. and *Mugil cephalus* L. that the fish gathering rates for the wave lengths of a single fish differ from those of the aggregated fish. (There is no clue to answer the question why risings in the curves appear in the case of aggregation. The further investigation is expected on this problem.) It is no doubt that this difference is caused by the fact that the state of aggregation produces some effects on psychology and behavior of the fish. As one of the factors which make this effect, the type of aggregation is doubtlessly important. It is easily supposed that when two fish are difficult to form an aggregation the result of the experiment of these fishes will be almost the same as one fish-experiment. This supposition is proved true by the fact that $C_{(1.1)}$ in Fig. 9 looks like $C_{(1)}$ ($=g_1$) both being almost horizontal. Accordingly, it must be considered that the curves of fish gathering rate which we have gained so far, include the ones which indicate the particular forms of aggregation. Besides this, these curves are mingled according to the ratio of RFA. However, if the number of fish are large, the curves of fish gathering rate effect only by the particular type of aggregation which shows the larger RFA among the conceivable types it is natural that time process of RFA should be various according to the combinations of fish. In two-fish experiment the behavior of each fish is more individual. If the

number of fish is many enough, an individual fish in a group scarcely separate itself from the aggregation. The fish which occasionally leave the aggregation will soon come back into a group. Accordingly, it is impossible to suppose ten fish (for instance) in an aggregation behave themselves independently. RFA of these fish is small enough to be neglected. The exception to this rule is the case in which is my research on the relation between PH of sea water and the phototaxis (1951). The fish gathering rate curve becomes horizontal as PH gets apart from 8.0. In this case, it is supposed, the fish are not in a group because of PH and show the tendency of individualization of fish.

At the two fish experiment, the conversion of aggregation expressed in $G_{(1.1)} \rightleftarrows G_{(2)}$, is proceeding. This relation is in a state of equilibrium when $G_{(2)} > G_{(1.1)}$. In other words, the grouping by two fish are easily made.

At the three fish experiment, the conversion is probably carried out as follow.

$$\begin{array}{ccc} & G_{(3)} & \\ \mathrm{I} \uparrow\downarrow & & \uparrow\uparrow \mathrm{III} \\ G_{(1.2)} & \rightleftarrows & G_{(1.1.1)} \\ & \mathrm{II} & \end{array}$$

The process I seems to take place frequently. When $G_{(3)}$ and $G_{(1.2)}$ are equal in number, the balance will be maintained. But the processes II and III hardly occur.

To take place the change, $G_{(1.2)} \rightarrow G_{(1.1.1)}$, it is necessary that one fish separated from two-fish groups should not go to another fish and that the left one also should make no group. Therefore this change scarcelly happens.

On the contrary, the change $G_{(1.1.1)} \rightarrow G_{(1.2)}$ takes place with ease, for fish are inclined to form aggregation, as explained in the expression $G_{(1.1)} \rightarrow G_{(2)}$. In the process III the conversion $G_{(3)} \rightarrow G_{(1.1.1)}$ occurs most scarcely. Therefore, the fish gathering curves dominated by the curves $C_{(3)}$ and $C_{(1.2)}$ indicate $G_{(3)}$ and $G_{(1.2)}$. Furthermore, as $G_{(1.2)}$ is composed of a two-fish aggregation and an one-fish aggregation, RFA is 0.5 : 0.5. Therefore the following relation is supposed.

$$C_{(1.2)} = 0.5C_{(2)} + 0.5C_{(1.1)}$$

The reason why $C_{(1)}$ was not employed is that one-fish aggregation has the two-fish aggregation as its opponent. Now, the value of this expression is calculate from $C_{(2)}$ and $C_{(1.1)}$ as follow.

mμ	430	470	500	530	570	610	660	720
Left side	10.2	13.4	20.2	17.5	12.3	10.3	10.1	6.0
Right side	10.8	12.8	19.4	18.3	11.6	11.4	9.2	6.7

It is now proved that the left side nearly equals to the right side in every case. Of course, it is possible that these accords are incidental.

Such measurement as we carried out, can be applied only on one or few-fish experiment. The phenomena which we wish to observe, probably occur in the experiment of few fish. Generally speaking, if the fish gathering curve for the wave lengths in case of N fish experiment is named $G_{(n)}$ and the actual RFA α, β, γ, δ...... and the fish gathering curve for each kind of fish group, C_α, C_β, C_γ, C_δ the following expressions are supposed to be formed.

$$\alpha+\beta+\gamma+\delta+\cdots\cdots=1$$
$$g_n=\alpha C_\alpha+\beta C_\beta+\gamma C_\gamma+\delta C_\delta+\cdots\cdots$$

However, the type of g_n will be influenced mostly by the one which is larger among α, β, γ, $\delta\cdots\cdots$,

SUMMARY

1. Shapes of the curves of fish gathering rate are varied in accordance with the number of fish employed in the experiment.
2. Fishes are constantly forming various type of aggregations. Some type of aggregations are easy to be formed but others are not. Observing these phenomena objectively, the author tried to show the rate of the frequency of appearance of each kind of aggregation in quantities.
3. The type of aggregation produce effects on the curve of fish gathering rate against the wave lengths. The usual curves of fish gathering rate in relation to the wave lengths are consist of the curves of fish gathering rate for every type of aggregation and are obtained through multiplying this by the rate of the frequency of appearance of each type of aggregation.

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